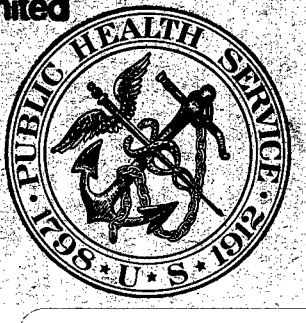
PUBLIC HEALTH BULLETIN

No. 188

STUDIES IN NATURAL ILLUMINATION IN SCHOOLROOMS

PART III



UNITED STATES TREASURY DEPARTMENT

PUBLIC HEALTH SERVICE

WASHINGTON, D. C.

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NOVEMBER, 1929

STUDIES IN NATURAL ILLUMINATION IN SCHOOLROOMS

PART III

EFFECT OF CLOUDS ON DAYLIGHT ILLUMINATION AND ON DAYLIGHT RATIOS

BY

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STUDIES IN NATURAL ILLUMINATION IN SCHOOLROOMS

PART III [1]

EFFECT OF CLOUDS ON DAYLIGHT ILLUMINATION AND ON DAYLIGHT RATIOS [2]

By A. F. BEAL, *Physicist, United States Public Health Service*

INTRODUCTION

SYNOPSIS

This bulletin is a summary of about 45,000 observations of daylight illumination made by the United States Public Health Service in a school building in Hagerstown, Md., during the school year 1923–24. The influence of clouds upon the inside illumination, the outside illumination, and the sky brightness has been made the subject of special study. Also, an analysis is made of the ratio of the inside illumination on a desk to the total outside illumination, (due to both skylight and direct sunlight), and of the ratio of the inside illumination to the outside sky brightness; the distribution of the light within the rooms, and the changes in the distribution accompanying changes in other factors or attendant circumstances; and, finally, an analysis is given showing the relationship, under varying cloud conditions, between the inside illumination and the area of the sky vault which is visible from each desk, and a generalized formula for forecasting inside illumination under any set of attendant conditions. At the end of the paper a summary of the conclusions is given.

PURPOSE

The problem of artificial illumination in factories has received considerable attention in recent years and is much further advanced as a science than that of daylight illumination of interiors. Natural lighting, however, is now receiving increasing attention. The cause of the delay in the development of the principles underlying the proper utilization of daylight is not evident. It may be due to the rather prevalent opinion that daylight is always abundant and costs nothing for maintenance, or to the difficulties introduced by the tremendous changes which occur in the outside daylight illumination in a very few minutes, such as is caused, for example, by the passing of a large cloud over the sun. It would seem, therefore, that a determination of the principles affecting the daylight illumination of interiors would be highly desirable. A knowledge of clearly defined,

[1] Parts I and II are contained in Public Health Bulletin No. 159. Studies in Natural Illumination in Schoolrooms. Parts I and II.

[2] Submitted for publication July 26, 1928.

adequately supported or proven, scientific principles concerning the daylighting of interiors would aid in obtaining more efficient illumination, and—of perhaps greater importance—in the conservation of vision.

SOURCE OF DATA

In order to obtain ample data which would be of value in determining the various factors affecting the natural illumination of interiors an experimental investigation of the daylighting of a typical modern school building was planned by Senior Surgeon Taliaferro Clark. All of the data were secured by, or under the direction of, the author, whose analysis of the results is presented in this paper. A school building at Hagerstown, Md., was selected for the investigation and about 45,000 determinations of illumination were made with a Macbeth illuminometer during 39 weeks, covering the school year 1923–24. The illumination was determined each hour on each of 24 selected school desks—6 desks in each of 4 rooms.[3] There were, therefore, about 1,840 observations for each desk, these being obtained during all kinds of weather conditions, during 7 hours of the day, and during 9 months of the year. Observations of the total outside illumination (illumination from sun and sky combined) and of the brightness of the sky were also made at the beginning and end of each hourly series of measurements on the school desks. The difference in time between these two outside measurements for each hourly series was usually only about 14 minutes. Whenever any use was made of the outdoor observations, such as in computing the ratio between the indoor illumination for each desk and the outside illumination or sky brightness, the mean of the two values of the outside illumination or of the sky brightness was used in each case. The observations were made hourly, averaging about 40 minutes after each hour, or from 9.40 a. m. to 3.40 p. m., seventy-fifth meridian time being used. The kind of weather existing at the time of the observations was also noted.

A preliminary study of the results obtained, based upon average conditions without reference to the influence of clouds, has been published as Public Health Bulletin No. 159. Another discussion of some of the results obtained has been published in the Transactions of the Illuminating Engineering Society for March, 1927. The present bulletin is a further analysis of this mass of data, made for the purpose of determining, if possible, some of the scientific principles underlying the daylighting problem. The most important problem considered is the influence of clouds upon daylighting.

[3] See footnote Studies in Natural Illumination in Schoolrooms, Parts I and II, Public Health Bulletin No. 159, p. 27.

DESCRIPTION OF THE BUILDING

An understanding of the character of the school building in which the observations were made at Hagerstown is necessary for a satisfactory interpretation of the data and conclusions which follow. The building is 2 stories in height and contains 20 classrooms arranged 5 on either side of a straight longitudinal corridor oriented 31° east of north. A floor plan and the four walls of room 104 on the first floor of the building are shown in Figure 1. This room is one of the four rooms in which the illumination observations were made. That the building deviates appreciably in direction from the points of the

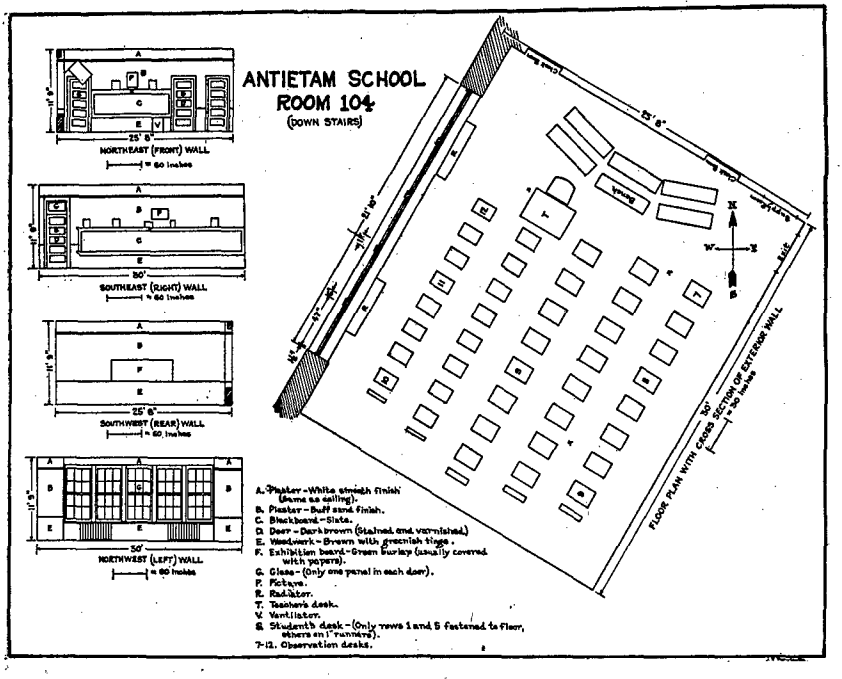

FIGURE 1.—Floor plan and elevation of the four walls of room 104

compass is illustrated by this figure. The figure, however, is specially intended to show the location of each of the desks with respect to the windows. The 6 desks in this room upon which observations were made are indicated by the numbers 7 to 12. The floor plans of the other 3 rooms in which observations were made are shown in Figure 2. A more complete description and some photographs of the building and its environment are given in Public Health Bulletin No. 159. Figure 2 of that bulletin is a map which shows the shape of the building and the location of the surrounding obstructions to light.

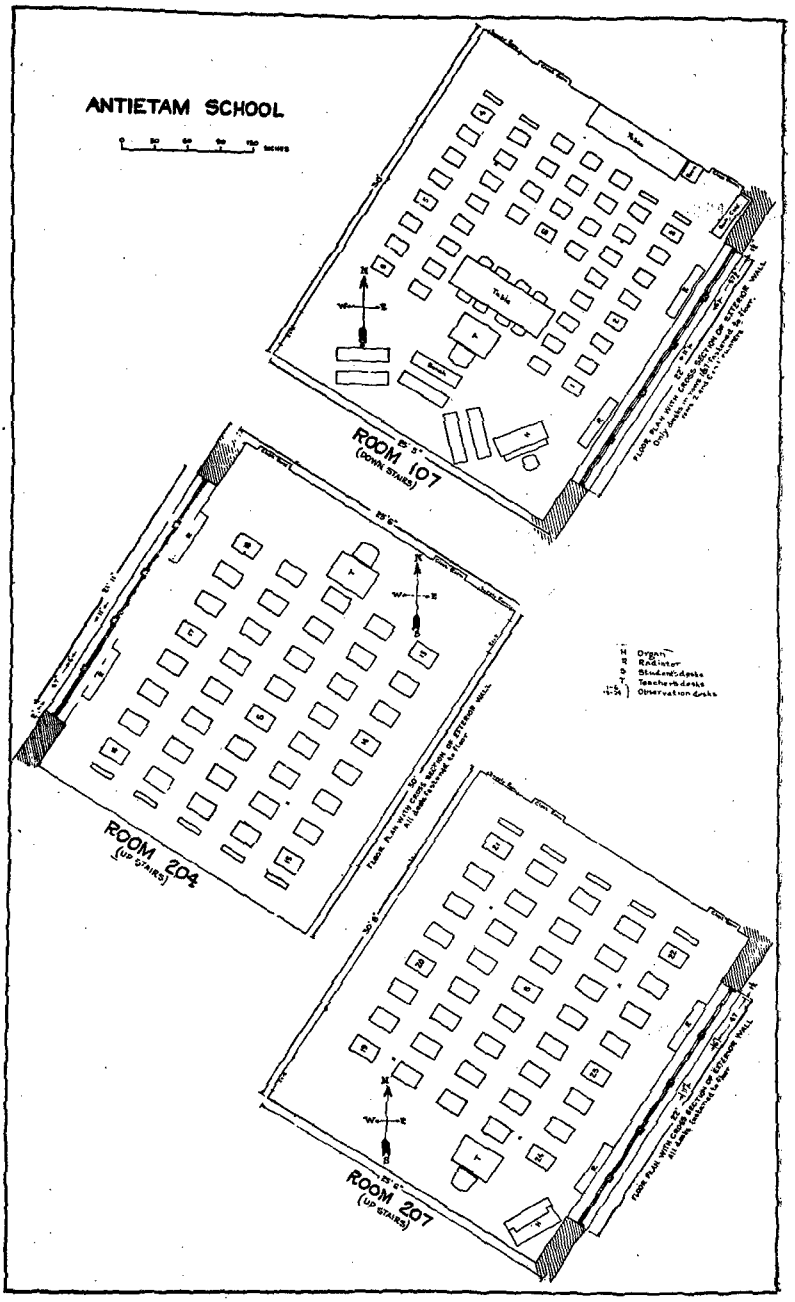

FIGURE 2.—Floor plans of rooms 107, 204, and 207

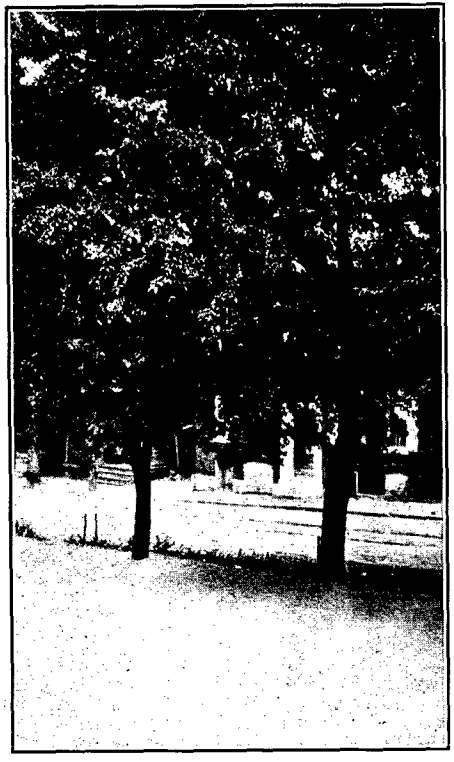

FIGURE 3.—View from middle window of Room 107 on the first floor, showing trees in summer foliage

FIGURE 4.—View of the same trees in summer foliage shown in Figure 3, but viewed from Room 207 on the second floor

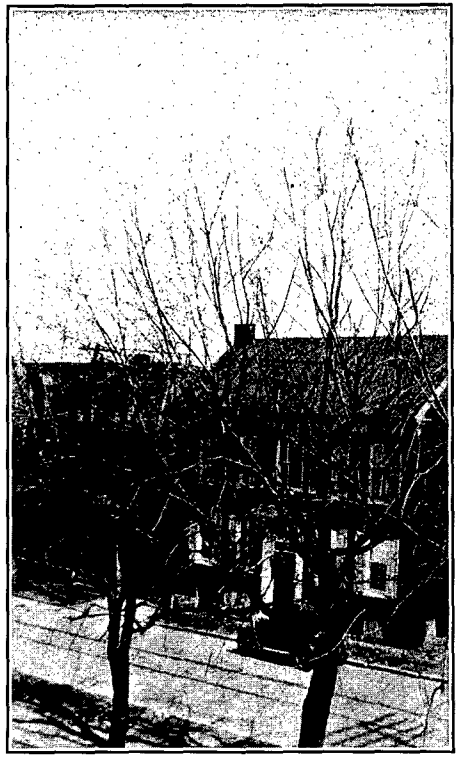

FIGURE 5.—View from Room 207 of the same trees as shown in Figure 4, but showing them in winter foliage

ENVIRONMENT

The obstructions tending to limit the sky vault visible from any of the desks are a row of trees on each side of the building about 35 feet distant; also, on the southeast side is a row of two-story residences about 90 feet distant. Three photographs showing different phases of the sky line are reproduced in Figures 3, 4, and 5 of this bulletin. Figure 3 shows a group of trees in summer foliage on the southeast side of the building as viewed horizontally from the window ledge on the first floor. Figure 4 shows the same trees given in Figure 3 but viewed horizontally from the window ledge on the second floor; and Figure 5 gives the same view of these trees from the second floor, but as they appear in winter, without foliage. The increase in the visible sky vault caused by the falling of the leaves is well illustrated by the differences between Figures 4 and 5.

ROOM DETAILS

As already mentioned, the illumination was measured each hour on six desks in each of four rooms. Two of the rooms were on the southeast side of the building, one room directly above the other, and two were on the northwest side of the building, one room directly above the other. All of the rooms had unilateral lighting. The desks selected in each room were the first, middle, and last desks in the row nearest the windows and the corresponding desks in the row farthest from the windows. (See figs. 1 and 2.) The seating arrangement was such that the windows were always on the left-hand side of the pupils. The window shades were always fully open whenever illumination measurements were made in a room. The area of the glass of the windows (excluding all mullions and portions of the sashes) was computed to be 17,415 square inches on the first floor, or about 16 per cent of the floor area; and on the second floor 14,175 square inches, or about 13 per cent of the floor area. These glass ratios were a trifle smaller than would have been expected from the apparent size of the windows owing to the fact that the rooms are about 26 feet wide. The location of each desk in the room and certain other physical factors or measurements pertaining to the desk which affect its illumination, are given in Table 1.

TABLE 1.—*Description and location of 24 selected school desks, Hagerstown, Md., upon which the illumination was measured from September 17, 1923, to June 15, 1924*

Desk No.	Room No.	Direction of exposure	Ratio of glass area to total floor area	Height above floor			Distance, desk center to—				Ratio of distance from glass to elevation of window top above desk	Visible sky vault June 20, 1924	
				Window glass		Desk top	Window glass	Wall opposite window	Northeast wall	Southwest wall		Square degrees	Reduced square degrees[1]
				Bottom	Top								
1	2	3	4	5	6	7	8	9	10	11	12	13	14
	First floor		*P. ct.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*			
1						22.6	59	246	237	123	0.59	1,830	1,130
2						22.6	59	246	164	196	.59	1,718	976
3	107	SE.	16.5	35	123	22.6	59	246	66	294	.59	1,022	616
4						22.6	262	43	65	295	2.61	128	20
5						22.6	262	43	164	196	2.61	135	33
6						22.6	262	43	237	123	2.61	82	23
7						24.5	258	50	99	261	2.62	345	76
8						24.5	258	50	183	177	2.62	352	88
9						26	258	50	294	66	2.66	180	32
10	104	NW.	16.3	35	123	22.8	63	245	298	62	.63	968	464
11						22.8	63	245	204	156	.63	1,748	846
12						22.8	63	245	132	228	.63	1,605	809
	Second floor												
13						29.5	255	51	80	280	3.02	284	62
14						29.5	255	51	178	182	3.02	304	62
15	204	NW.	13.3	41	114	29.5	255	51	311	49	3.02	120	27
16						28	62	244	311	49	.74	938	367
17						28	62	244	178	182	.74	2,108	984
18						28	62	244	80	280	.74	1,601	773
19						28	254	52	280	88	2.96	225	46
20						28	254	52	185	183	2.96	330	61
21	207	SE.	13.1	41	114	28	254	52	53	315	2.96	308	62
22						28	63	243	53	315	.75	1,410	564
23						28	63	243	185	183	.75	2,378	1,037
24						28	63	243	280	88	.75	2,092	953

[1] Described on p. 96.

The second column of the table gives the number of the room and the floor of the building upon which each of the 24 selected desks is located. The third column shows the direction toward which the windows are faced, and the fourth column gives the glass-area-floor-area ratio previously mentioned. The remaining columns of the table, particularly columns 7 to 14, give dimensions pertaining to or affecting each desk individually. For desk No. 14 in room 204, for example, the bottom of the window glass is 41 inches above the floor (column 5), or 11.5 inches above the top of the desk which is 29.5 inches high (column 7). The top of the window glass is 114 inches above the floor, (column 6), or 84.5 inches above the top of this desk. The center of desk No. 14 is 255 inches from the plane of the window glass (column 8); this is 3.02 times (column 12) the distance (84.5 inches) from the desk top to the top of the window glass. The center of this desk is also 51 inches from the right-hand or southeast wall of the room, 178 inches from the front wall, and 182 inches from the rear wall of the room. In the last two columns of the table

there is given the area of the sky which could be seen from the center of the desk on June 20, 1924. This quantity will vary with the season, since the sky line or the line forming the bottom of the visible portion of the sky was usually formed by tree tops as shown in Figures 4 and 5 for example. The area of the visible sky vault expressed in "square degrees," the unit used in making the measurements, is given in column 13 of Table 1, it is also given in the fourteenth column expressed in the unit devised by Cohn known as "reduced square degrees."[4] This quantity is obtained by multiplying the existing number of "square degrees" by the trigonometric sine of the angle of elevation of the middle of the visible portion of the sky.

THE INFLUENCE OF CLOUDS UPON ILLUMINATION AND SKY BRIGHTNESS

An important cause of variation in daylight which is apparent to even the casual observer is the influence of clouds. Clouds exert a tremendous influence upon the illumination, much more in fact that is suspected by the unaided eye. This is well shown by continuous records of daylight such as are being made daily by the office of industrial hygiene of the United States Public Health Service, in Washington, D. C. One of these graphic records is reproduced as Figure 1 in Public Health Bulletin 159. In these records it is seen that in a very short space of time when clouds pass over the sun the illumination will drop to a point only about 25 per cent of that prevailing when the sun is not obscured. An accurate determination of the influence of clouds upon the illumination, and especially the indoor illumination, is, therefore, much to be desired.

OUTSIDE OBSERVATIONS

The observations for outside illumination and sky brightness were made on a near-by vacant lot. The observations for outside illumination were made with the test plate free from any shade. The outside illumination includes the illumination from the sky as well as that direct from the sun. The observations for sky brightness were always made at the spot opposite to and 90° from the sun, unless there existed at that spot a condition of cloudiness not typical of the entire sky vault. In that case the observation was made as close to this spot as was reasonably possible, but at a place judged to be representative of the cloudiness and brightness of the entire sky.

CLASSIFICATION OF CLOUDS

In analyzing the data, the observations for clouds were divided into eight arbitrarily chosen classes depending upon two things, i. e., whether the clouds were thick or thin, and upon the percentage of the

[4] A more complete discussion of the "reduced square degree" is given on p. 44 of Public Health Bulletin 159, as well as on p. 96 of this bulletin.

sky which the clouds covered. Of the 8 classes, 1 is for no clouds, 4 are for thick clouds, and 3 are for thin clouds. It has been found convenient, however, to use the class of zero clouds as the first of five classes of thick clouds. At the time the observations for clouds were made, they were recorded in terms of the 10 generally adopted kinds and the number of tenths of sky obscured. The clouds classified herein as thin included the cirrus varieties, namely, cirrus, cirro-stratus, and cirro-cumulus. For the purposes of this study the remaining seven kinds were grouped together as thick clouds, these kinds being cumulus, stratus, alto-stratus, alto-cumulus, strato-cumulus, nimbus, and cumulo-nimbus. It should be emphasized that "class" of clouds as used in this bulletin refers to both the portion of sky covered and whether the clouds were thick or thin, and does not refer directly to any of the ten "kinds" used by meteorologists, viz, cumulus, cirrus, etc., except insofar as the kind indicates whether the clouds be thick or thin.

The estimated number of tenths of sky vault covered by clouds at any time is open to several interpretations unless there is specified the principles followed in making the estimation. With the sky only partially covered with clouds rising a number of hundred feet above their bases (the latter probably being at the same level), an observer looking directly overhead will see considerable blue sky, but near the horizon there will be little if any blue sky visible owing to the oblique angle of view and the thickness of the clouds. In other words, the portion of the blue sky visible to an observer at one fixed location is not the same as the portion of direct sunlight reaching the surface of the earth over an area a number of square miles in extent. In this work the principle followed was to estimate the percentage of the hemisphere of sky vault which could not be seen by an observer at one fixed location.

In like manner, the estimated percentage of sky covered by thin clouds is subject to interpretation and standardization. If a thin hazy cirrus cloud through which the sun or moon can be seen, be present over the entire sky vault, there is a question as to whether the portion of the sky which is covered should be considered as ten-tenths, or if there should be used a number considerably less, such as four or five tenths. In this work and under conditions just enumerated, the value ten-tenths was used because if the presence of the thin clouds would have any influence upon the outside illumination and sky brightness (which they did have) the entire sky vault would be affected and the number used to indicate the degree of cloudiness should represent the entire sky vault; the recorded kind of clouds would be expected to tell the remainder of the story. For fractional portions of the sky covered by thin clouds, the same principle was followed in estimating the number of tenths covered.

TABLE 2.—*Combinations of clouds observed, in tenths of sky covered, at the beginning and end (or vice versa) of each hourly series, which were incorporated into each adopted class of clouds*

Adopted cloud classification or class	Cloud combinations included in each class
	THICK CLOUDS
0	0-0
2	0-1, 0-2, 0-3, 0-4, 1-1, 1-2, 1-3, 1-4, 1-5, 2-2, 2-3, 2-4, 3-3
5	2-5, 2-6, 3-4, 3-5, 3-6, 3-7, 4-4, 4-5, 4-6, 4-7, 4-8, 5-5, 5-6, 5-7, 6-6, 6-7
8	5-8, 5-9, 6-8, 6-9, 6-10, 7-7, 7-8, 7-9, 7-10, 8-8, 8-9, 8-10, 9-9, 9-10
10	10-10
	THIN CLOUDS
0	0-0
A	0-1, 0-2, 0-3, 0-4, 0-5, 1-1, 1-2, 1-3, 1-4, 1-5, 2-2, 2-3, 2-4, 2-5, 3-3, 3-4, 3-5, 4-4, 4-5, 5-5
B	1-6, 2-6, 2-7, 3-6, 3-7, 3-8, 4-6, 4-7, 4-8, 4-9, 5-6, 5-7, 5-8, 5-9, 5-10, 6-6, 6-7, 6-8, 6-9, 6-10, 7-7, 7-8, 7-9, 7-10, 8-8, 8-9, 8-10
C	9-9, 9-10, 10-10

For each hourly series of illumination measurements there are two sets of cloud observations as well as two measurements each of the outside illumination and of the sky brightness. In the elapsed time of about 14 minutes between the first and second cloud observations there usually were important changes. For example, at the time of one observation the clouds might have obscured two-tenths of the sky while at the other observation six-tenths of the sky might have been covered. To harmonize these differences so as to obtain a suitable value to represent the number of clouds in connection with the mean of the two outside illumination measurements was an important

step. Some kind of a classification was necessary, and although it is not essential that a justification of the classification be made at this point, the results which follow show, it is believed, that a satisfactory basis of classification of the observed number of clouds was obtained.

The adopted classification of clouds is given in Table 2. This table shows the various combinations of the number of clouds observed which were grouped together to form the eight adopted classes. The values given in the table occur in pairs, and indicate the number of tenths of sky vault covered by clouds observed at the beginning and end, or, vice versa, the end and the beginning, of each hourly series of observations. The various combinations for thick clouds were determined by permitting within each class a maximum difference of four-tenths between the number of clouds observed at the beginning and at the end of the hourly series; and for thin clouds the maximum difference permitted within each class was five-tenths. Observations showing differences in excess of these values were rejected (called class X).

One suitable class of clouds was formed by including only the observations when no clouds were visible at either the beginning or end of the hourly series of observations. Another class, easily decided upon, was for those observations when there were ten-tenths of thick clouds at both the beginning and end of the series; that is, the sky was totally overcast with thick clouds. The remaining 3 classes for thick clouds, designated as two, five, and eight tenths, were chosen by combining a large number of possible combinations which are given in Table 2. Class A included those observations showing nothing larger than five-tenths thin clouds; class C included those showing nothing less than nine-tenths thin clouds; and class B included all other values, subject, of course, to the limitation as to the range of five-tenths permitted within each class for thin clouds. When both thick and thin clouds were present, in classifying the thick clouds, the thin clouds up to three-tenths were ignored, and in classifying the thin clouds in excess of three-tenths, the thick clouds up to two-tenths were ignored. All others were rejected, (included in class X).

In this connection it is well to keep in mind that there is no certainty as to the cloud condition existing at the time of the observation of the inside illumination for any particular desk. The cloud observations apply only to the conditions existing at the beginning and end of each hourly series, and the intervening observations for each of the 24 desks were classified on this basis. It is quite possible, however, that occasionally for some of the desks the cloud conditions existing at the time the illumination was actually measured may have deviated considerably from that indicated by the conditions prevailing

at the beginning and end of the series. If this situation did occur, it probably happened most frequently in the case of the intermediate classes of thick clouds, such as two, five, and eight tenths, when the proximity of one large cloud to the zenith of the observer would materially affect the amount of the sky eclipsed; it probably occurred least frequently in the case of observations with a cloudless sky or a totally covered sky, as these conditions are usually more stable than the intermediate classes. From these reasons as well as from reasons given later, such as the larger number of observations for these two cloud classes (discussed in the following paragraph), greater accuracy is probably attained in the case of cloud classes zero and ten-tenths than in the case of the intermediate classes two, five, and eight tenths.

NUMBER OF OBSERVATIONS FOR EACH CLASS OF CLOUDS

Since the observations were made at a fixed time once each hour and independent of the weather or condition of cloudiness, it is important to know the number of observations which were made under each of the eight adopted classes of clouds. This information is important in order to know for which cloud classes the various mean values and conclusions which follow are the more reliable, and the relative accuracy to which values for each class are entitled. Information of this character is given in Table 3, which shows the number of observations for each cloud class for each hour and month, as well as for all the nine months together.

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TABLE 3.—*Number of pairs of observations of outside illumination and for each desk, classified by clouds for each hour and month, Hagerstown, Md., September 17, 1923, to June 15, 1924*

Cloud class	Number of observations								
	All hours		9.40	10.40	11.40	12.40	1.40	2.40	3.40
	Number	Per cent							
ALL MONTHS—OCTOBER TO JUNE[1]									
0	370	20	61	56	55	51	48	49	50
2	181	10	16	22	26	28	27	29	33
5	157	8	18	18	30	28	27	20	16
8	178	10	27	27	28	24	23	25	24
10	545	30	86	76	71	76	73	82	81
A	149	8	24	19	21	24	19	21	21
B	110	6	16	15	10	12	22	19	16
C	90	5	7	13	13	14	14	12	17
X	60	3	6	13	9	8	11	7	6
Total	1,840	100	261	259	263	265	264	264	264
OCTOBER[1]									
0	69	34	10	11	12	9	9	10	8
2	29	15	0	3	2	4	5	8	7
5	24	12	1	1	5	7	5	2	3
8	16	8	3	3	3	2	1	2	2
10	23	12	5	3	3	2	3	4	3
A	19	9	6	1	1	2	3	3	3
B	14	7	3	3	2	2	2	0	2
C	0	0	0	0	0	0	0	0	0
X	6	3	0	2	1	1	1	0	1
Total	200	100	28	27	29	29	29	29	29
NOVEMBER[1]									
0	71	34	7	8	9	11	11	13	12
2	11	5	2	3	1	1	3	1	0
5	3	1	0	0	1	1	0	1	0
8	21	10	4	3	4	4	2	3	1
10	73	35	11	10	7	10	10	11	14
A	14	7	3	2	3	1	1	1	3
B	3	1	1	1	1	0	0	0	0
C	10	5	2	3	1	1	1	1	1
X	5	2	0	0	2	1	2	0	0
Total	211	100	30	30	29	30	30	31	31
DECEMBER[1]									
0	23	12	4	2	2	4	4	3	4
2	11	6	1	1	1	1	1	4	2
5	14	7	0	3	4	1	4	1	1
8	22	12	5	2	2	4	2	1	6
10	57	30	9	8	7	8	7	10	8
A	14	7	2	2	3	1	2	1	3
B	19	10	1	4	2	2	3	6	1
C	18	10	1	3	4	6	2	0	2
X	11	6	4	2	2	0	2	1	0
Total	189	100	27	27	27	27	27	27	27
JANUARY[1]									
0	58	31	8	7	9	9	8	9	8
2	21	11	2	3	3	4	4	2	3
5	8	4	1	0	3	1	1	2	0
8	17	9	4	3	3	2	2	0	3
10	49	26	9	8	7	7	6	6	6
A	14	8	2	3	1	2	1	3	2
B	9	5	0	0	0	1	4	2	2
C	2	1	0	0	1	0	0	0	1
X	9	5	0	3	0	1	1	3	1
Total	187	100	26	27	27	27	27	27	26

[1] Interval ending on the 15th day of the indicated month.

TABLE 3.—*Number of pairs of observations of outside illumination and for each desk, classified by clouds for each hour and month, Hagerstown, Md., September 17, 1923, to June 15, 1924*—Continued

Cloud class	Number of observations								
	All hours		9.40	10.40	11.40	12.40	1.40	2.40	3.40
	Number	Per cent							
FEBRUARY [1]									
0	31	14	5	4	5	5	4	4	4
2	12	6	2	0	1	2	1	2	4
5	14	6	2	2	2	2	3	1	2
8	40	19	4	6	8	2	4	9	7
10	80	37	13	12	11	13	10	11	10
A	10	5	1	2	1	2	2	1	1
B	8	4	2	2	2	1	1	0	0
C	3	1	0	0	0	0	1	1	1
X	17	8	1	3	1	4	4	2	2
Total	215	100	30	31	31	31	30	31	31
MARCH [1]									
0	26	13	5	5	4	3	3	3	3
2	22	11	3	2	5	4	3	2	3
5	17	8	2	1	5	3	4	2	0
8	20	10	2	4	2	3	2	4	3
10	56	28	9	10	8	7	6	8	8
A	28	14	4	4	4	6	4	2	4
B	17	8	1	1	0	2	5	4	4
C	13	7	2	1	1	1	2	3	3
X	2	1	1	0	0	0	0	0	1
Total	201	100	29	28	29	29	29	28	29
APRIL [1]									
0	48	22	11	11	9	6	4	2	5
2	21	10	1	4	4	3	2	4	3
5	26	12	4	2	2	6	5	2	5
8	11	5	1	0	2	1	4	3	0
10	57	27	8	7	7	8	8	10	9
A	21	10	2	2	4	5	2	4	2
B	15	7	3	1	0	2	5	2	2
C	12	6	0	2	2	0	1	3	4
X	2	1	0	1	1	0	0	0	0
Total	213	100	30	30	31	31	31	30	30
MAY [1]									
0	32	15	6	6	3	4	4	5	4
2	25	12	4	2	5	4	3	2	5
5	24	12	4	4	3	4	1	6	2
8	14	7	1	3	1	2	3	2	2
10	68	33	10	10	11	10	11	8	8
A	13	6	2	1	3	2	2	1	2
B	9	4	2	1	0	1	1	2	2
C	20	10	1	1	2	3	5	4	4
X	3	1	0	1	1	0	0	0	1
Total	208	100	30	29	29	30	30	30	30
JUNE [1]									
0	12	6	5	2	2	0	1	0	2
2	29	13	1	4	4	5	5	4	6
5	27	13	4	5	5	3	4	3	3
8	17	8	3	3	3	4	3	1	0
10	82	38	12	8	10	11	12	14	15
A	16	7	2	2	1	3	2	5	1
B	16	7	3	2	3	1	1	3	3
C	12	6	1	3	2	3	2	0	1
X	5	2	0	1	1	1	1	1	0
Total	216	100	31	30	31	31	31	31	31

[1] Interval ending on the 15th day of the indicated month.

Based upon the nine-month average, 20 per cent of the observations were made at a time when the sky was cloudless (class 0); thick clouds (classes 2, 5, 8, and 10) were noted in the case of 58 per cent of the observations; thin clouds (classes A, B, and C) were observed for 19 per cent of the time; and only 3 per cent were rejected (class X) because of excessive change in the number of clouds between the beginning and end of each hourly series, these cloud observations being such combinations as do not appear in Table 2.

When the number of observations for the individual months (all hours) as given in Table 3 are examined, considerable variation is found. For example, during October (actually September 17 to October 15) the number of observations made which fell into the zero cloud class was 34 per cent of the total for the month, while in June it was only 6 per cent; the average for the nine months was 20 per cent, as formerly noted. For the ten-tenths class of clouds, the values ranged from an initial value of 12 per cent in October to a final value of 38 per cent in June, the average being 30 per cent. Based upon the nine-month average, 50 per cent of the observations fell into the two classes designated as zero and ten-tenths, while for individual months the values of the total for these two classes ranged from 41 per cent in March to 69 per cent in November, the remainder being distributed among the other six classes (2, 5, 8, A, B, and C), and the observations rejected (class X). It is evident, therefore, that the accuracy is much greater in the case of mean values obtained for cloud classes zero and ten-tenths than for any of the other six classes. The conclusions of this bulletin are based largely upon the results for these two cloud classes, but the results for the other classes are given (except for a few cases when not present), since they generally fall in line with the other values on the graphs and therefore give good corroborative evidence in support of the conclusions. In forming some of the conclusions, however, such as comparisons between the relative influence of thick clouds and thin clouds, it is necessary to take all the averages at their face value and as of equal accuracy. This is believed quite satisfactory in this work, for on those occasions when this is necessary the conclusions usually agree with what would be expected from a theoretical consideration of the subject.

INFLUENCE OF CLOUDS

The illumination data when classified by clouds alone is shown in Figure 6. In the means represented by the bars of this figure the effects of all other factors which cause variations in illumination are averaged together. This figure shows the average illumination results for six kinds of measurements, each classified according to the eight arbitrarily chosen cloud classes. The 6 measurements are the indoor illumination for 4 (Nos. 14, 20, 17, and 23) of the 24 desks

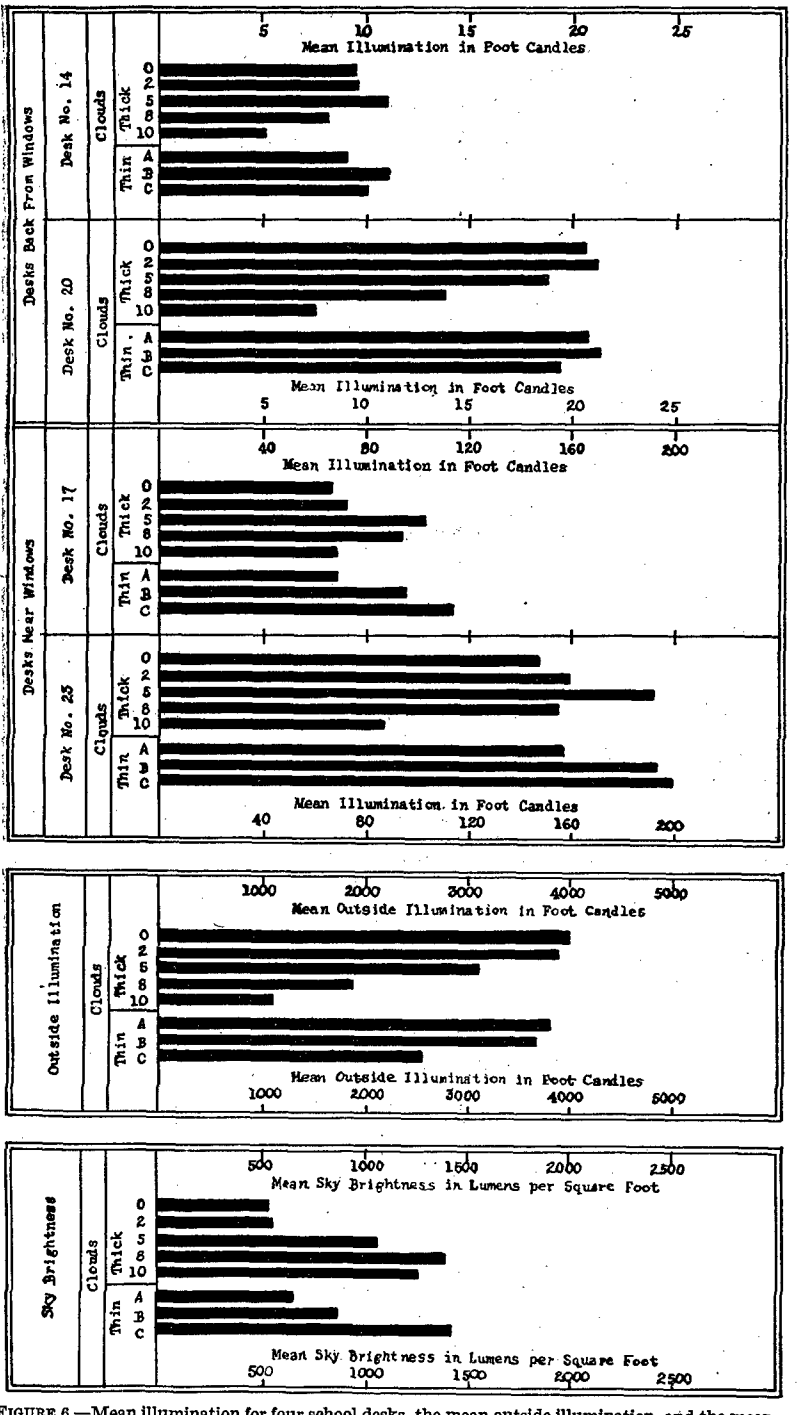


FIGURE 6.—Mean illumination for four school desks, the mean outside illumination, and the mean sky brightness, for each of eight classes of clouds, Hagerstown, Md., September 17, 1923, to April 15, 1924

upon which measurements were made, the outside illumination, and the brightness of the sky. Desks Nos. 14 and 20 are the middle desks in the rows farthest from the windows in the two rooms on the second floor; Nos. 17 and 23 are the middle desks in the rows nearest the windows in the same rooms as desks Nos. 14 and 20. Desks Nos. 14 and 17 had a northwest exposure, i. e., the windows of the room in which the desks were situated faced the northwest, while desks Nos. 20 and 23 had a southeast exposure. The sky view for desks Nos. 14 and 17 was partially obstructed by a large tree, while that for desks Nos. 20 and 23 was affected to a lesser extent by a row of smaller trees about 35 feet from the building.

One of the salient features portrayed in the bar graph, Figure 6, is that the presence of thin clouds reduces the illumination much less than thick clouds. In fact, there is a tendency for the illumination to be increased by the thin clouds. In general, both inside illumination and outside illumination decrease as the proportion of the sky overcast increases from zero to ten-tenths, while for the sky brightness the reverse is true. In a comparison of the results for desk No. 20 with those for the outside illumination (the bars for zero clouds for these two quantities are about the same length) it is seen that the outside illumination decreases more rapidly as the extent of cloudiness increases than does the illumination for desk No. 20.

The fundamental source data are given in six large tables (designated Table A to Table F) in the appendix of this bulletin. All tables of averages, graphs, and conclusions in this bulletin are based upon suitable averages of the data given in these six tables.

TABLE 4.—*Monthly mean values of outside illumination, arranged for each month and class of clouds, Hagerstown, Md., as derived from 7 mean hourly values for each month, September 17, 1923, to April 15, 1924*

Clouds	All months	Mean outside illumination in foot-candles						
		Oct.[1]	Nov.[1]	Dec.[1]	Jan.[1]	Feb.[1]	Mar.[1]	Apr.[1]
0	3,936	4,999	4,308	2,977	2,285	3,849	3,856	5,276
2	3,887	5,218	4,420	2,760	2,337	3,498	4,171	4,806
5	3,083	3,515	3,131	2,285	1,953	2,816	3,626	4,253
8	1,875	2,379	1,675	1,444	1,349	1,966	2,117	2,198
10	1,119	1,835	930	718	620	1,284	1,224	1,219
A	3,754	5,069	4,149	2,460	2,502	3,037	4,212	4,850
B	3,639	5,229	3,940	2,147	1,637	4,143	3,954	4,422
C	2,546	---------	2,187	2,159	1,430	2,409	3,423	3,665

[1] Interval ending on the 15th day of the indicated month.

SEASONAL AND DIURNAL VARIATIONS

By averaging the seven hourly values of the outside illumination for each month, there is obtained a mean value for each kind of clouds and for each month. Such values for each month and class of clouds are given in Table 4 and are shown graphically in sections A and B of Figure 7. The values for the thick clouds are represented in

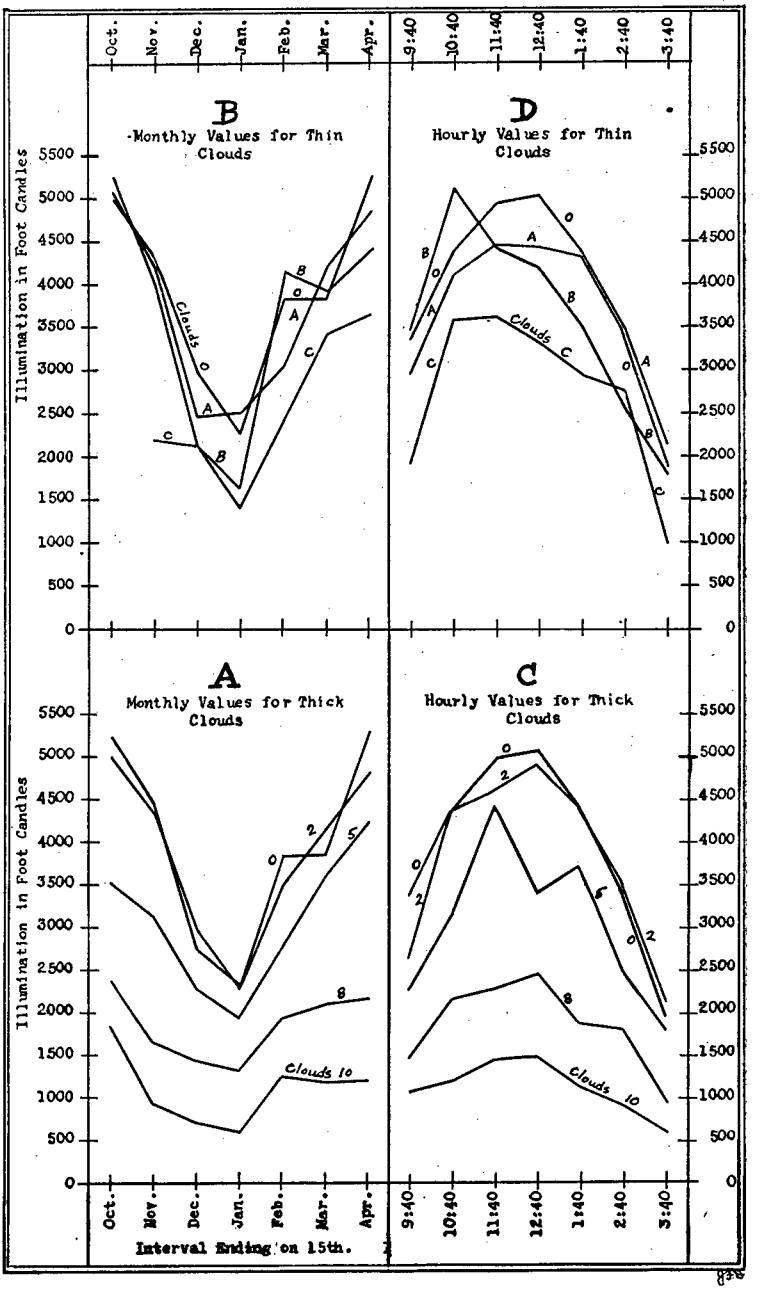


FIGURE 7.—Mean outside illumination for eight classes of clouds. Arranged by months, September 17, 1923, to April 15, 1924, and by hour of observation, 9.40 a. m. to 3.40 p. m., Hagerstown, Md.

Figure 7, section A, while those for the thin clouds are shown in Figure 7, section B. In this figure there is graphed a line for each class of clouds, the horizontal scale being the month of the year. The line for zero clouds is given in both sections A and B in order that it may be readily available as a standard of comparison for the thin clouds as well as for the thick clouds. Each line of the graph bears a number indicating the cloud class. In general, the numbers are placed above the lines to which they refer. This practice is followed in order to avoid confusion in identifying and interpreting the lines.

In like manner, if the values for each hour for the various months from October to April (for the illumination, the values for only the months October to April are used—see footnote, p. 2) are averaged together, there is obtained a mean value for each hour and kind of clouds. Such values are given in Table 5, and shown graphically in sections C and D of Figure 7. The construction of the graphs in sections C and D of this figure is the same as in sections A and B, except that in C and D the horizontal scale is the hour of the day rather than the month of the year.

TABLE 5.—*Hourly mean values of outside illumination, arranged for each hour and class of clouds, Hagerstown, Md., as derived from 7 mean monthly values for each hour, September 17, 1923, to April 15, 1924*

Clouds	All hours	Mean outside illumination, in foot-candles						
		9.40	10.40	11.40	12.40	1.40	2.40	3.40
0	3,936	3,397	4,411	4,968	5,066	4,414	3,364	1,929
2	3,807	2,680	4,392	4,601	4,902	4,421	3,527	2,123
5	3,032	2,270	3,116	4,392	3,423	3,730	2,508	1,786
8	1,859	1,485	2,170	2,285	2,448	1,855	1,809	958
10	1,119	1,083	1,204	1,451	1,471	1,123	902	596
A	3,754	2,980	4,136	4,485	4,669	4,346	3,508	2,155
B	3,610	3,500	5,147	4,445	4,227	3,545	2,591	1,815
C	2,764	1,976	3,599	3,655	3,366	2,966	2,799	986

Similar mean values of these kinds were obtained for the sky brightness. The seasonal values are given in Table 6 and shown graphically in sections A and B of Figure 8, while the hourly values are given in Table 7 and represented graphically in sections C and D of Figure 8.

TABLE 6.—*Monthly mean values of sky brightness, arranged for each month and class of clouds, Hagerstown, Md., as derived from 7 mean hourly values for each month, September 17, 1923, to April 15, 1924*

Clouds	All months	Mean sky brightness in lumens per square foot						
		Oct.[1]	Nov.[1]	Dec.[1]	Jan.[1]	Feb.[1]	Mar.[1]	Apr.[1]
0	529	465	395	365	373	693	745	669
2	555	613	436	440	386	599	605	806
5	1,062	872	1,135	778	701	1,120	1,476	1,355
8	1,374	1,612	1,080	1,018	896	1,660	1,718	1,634
10	1,249	1,781	945	797	744	1,495	1,474	1,509
A	652	580	417	396	395	1,409	629	740
B	865	910	616	874	491	816	1,124	1,226
C	1,422	---------	1,033	1,064	714	1,385	2,072	2,264

[1] Interval ending on the 15th day of the indicated month.

TABLE 7.—*Hourly mean values of sky brightness, arranged for each hour and class of clouds, Hagerstown, Md., as derived from 7 mean monthly values for each hour, September 17, 1923, to April 15, 1924*

Clouds	All hours	Mean sky brightness in lumens per square foot						
		9.40	10.40	11.40	12.40	1.40	2.40	3.40
0	529	452	563	620	627	568	478	396
2	552	450	574	510	715	610	508	500
5	1,056	1,041	1,296	1,160	1,157	1,117	919	700
8	1,368	1,132	1,554	1,578	1,631	1,431	1,411	842
10	1,238	1,072	1,378	1,617	1,500	1,377	1,009	714
A	548	467	560	594	620	597	539	458
B	919	981	799	991	1,167	812	993	687
C	1,508	1,212	1,783	1,700	1,309	1,696	1,895	961

A detailed study of the seasonal curves of the outside illumination (sections A and B of fig. 7) shows a well-defined mid-winter minimum. This is in agreement with the curve for the general average of all the observations (same as weighted average for each cloud class including class X) shown in Figure 14 of Bulletin 159. It is especially true (fig. 7, this bulletin) when the sky is not heavily overcast with clouds, and applies to all three classes of thin clouds as well as the smaller classes of thick clouds (classes 2 and 5). For the higher classes of thick clouds (classes 8 and 10) the seasonal minimum is present but does not appear so well defined as is the case for the smaller classes. As may be seen from the position of the curves for the five cloud classes in section A of the figure, the actual illumination in foot-candles decreases materially as the number of clouds increases. On the other hand, when only one curve is considered at a time, the percentage change between the seasons in the curves for many clouds is perhaps a trifle less than that in the curves for few clouds; and the actual change in foot-candles is also smaller for the higher classes, thereby making the illumination more nearly constant for the higher classes than for the lower classes, although the actual illumination is smaller.

In like manner, in Figure 7, sections C and D, there is a daily maximum near noon for each class of clouds, such as was found to be the case for the general average shown in Figure 11, of Public Health Bulletin 159. For these daily curves as well as for the seasonal curves, the actual values of the illumination in foot candles decrease as the number of clouds increase. The change in foot candles for each class of clouds is also seen to be less in curves for many clouds than in the curves for few clouds. In both cases, i. e., the seasonal and the daily curves, the graphs for ten-tenths clouds are approximately horizontal as compared with those for the other classes. This shows that for all hours of the day (9.40 a. m. to 3.40 p. m.) and all months (October to April) the outside illumination for ten-tenths clouds is more nearly constant than it is for the smaller classes, zero clouds for example. From the standpoint of illumination, the presence of many clouds is a disadvantage in that the actual illumination in foot candles is less than it is for few clouds, but this possibly is partially offset by the fact that the illumination is more nearly constant.

The curves for the sky brightness given in the four sections of Figure 8 show the same general characteristics just noted for the outside illumination except for the direction of change when an increase occurs in the extent of cloudiness. The outside illumination decreases as the number of clouds increases, but the sky brightness, according to these observations, increases. Other differences of varying importance can be noted between Figures 7 and 8. For example, in Figure 7 for the outside illumination, the curves most nearly horizontal are those for many clouds, while in Figure 8 for the sky brightness the curves that are most nearly horizontal are those for few or no clouds. In like manner, the curves for which the values are lowest are for many clouds in the case of the outside illumination and for few clouds in the case of the sky brightness. On the other hand, the curves showing the larger variations are the higher in each case, being for few clouds in the case of the illumination and for many clouds in the case of the sky brightness.

Since the data obtained for all the desks are rather extensive, four desks have been selected as being more or less typical of the others, and a detailed analysis made of the data for them. These four desks, Nos. 14 and 20, and 17 and 23, are the same four desks included in the bar graph Figure 6. As previously stated, desks Nos. 14 and 20 are the middle ones in the rows of desks farthest from the windows; Nos. 17 and 23 are the middle desks in the rows nearest the windows. Desks Nos. 14 and 17 have a northwest exposure; Nos. 20 and 23 have a southeast exposure. The values for the inner desks, Nos. 14 and 20,

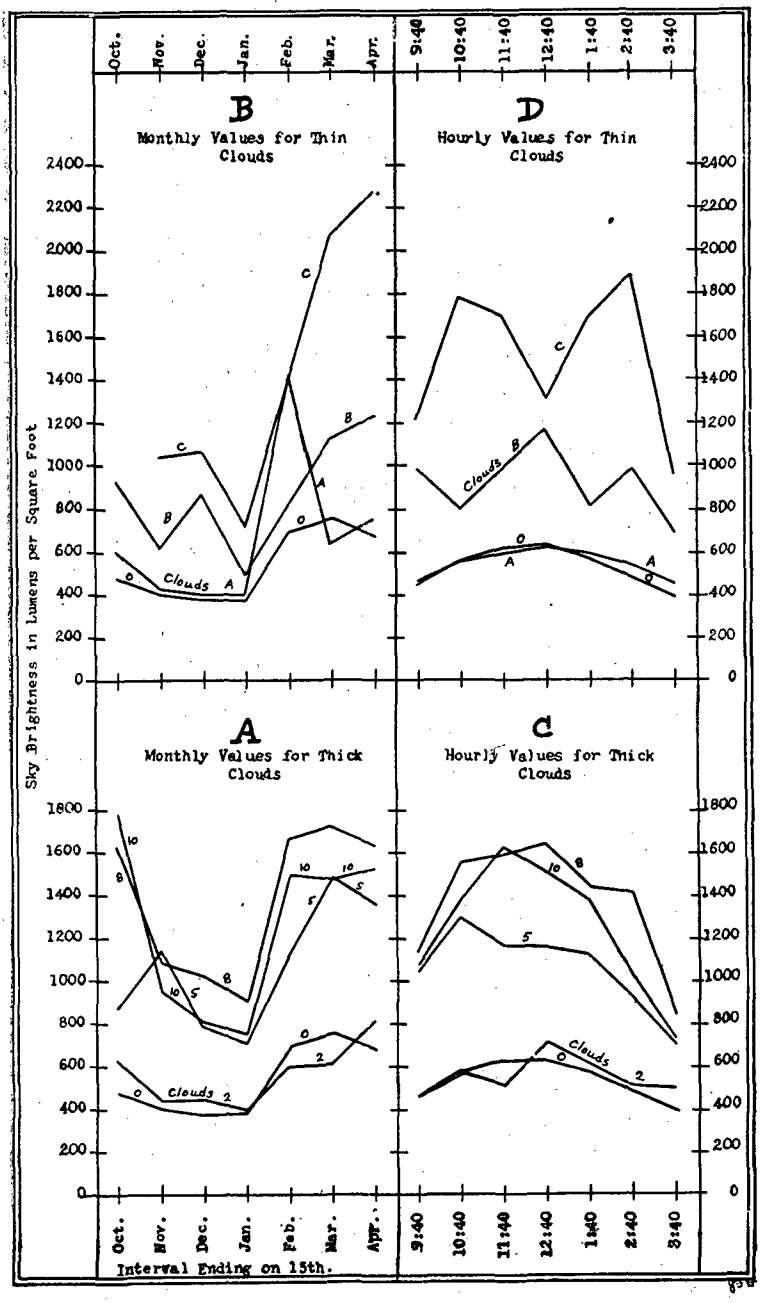


FIGURE 8.—Mean sky brightness for eight classes of clouds. Arranged by months, September 17, 1923, to April 15, 1924, and by hour of observation, 9.40 a. m. to 3.40 p. m., Hagerstown, Md.

are portrayed graphically in Figures 9 and 10, while those for the desks near the windows are given in Figures 11 and 12, but with a different scale of ordinates from that used in Figures 9 and 10. Each of these figures is divided into sections showing seasonal and hourly variations of the illumination for thick and thin clouds, in a similar way to Figures 7 and 8 for the outside illumination and the sky brightness.

The graphs for these four desks, and especially for the inner desks Nos. 14 and 20, show very little similarity to the corresponding

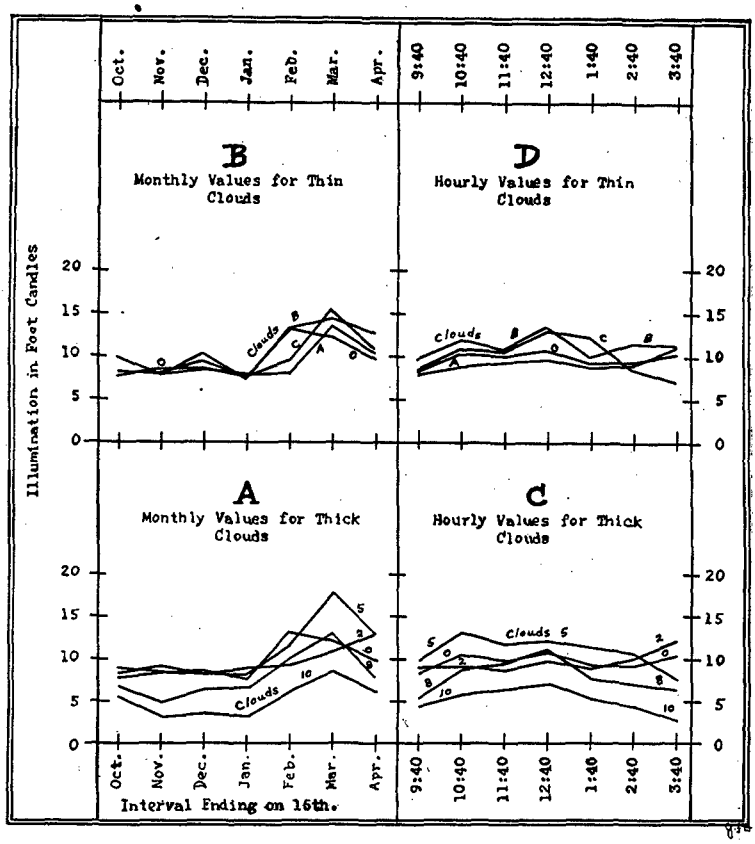


FIGURE 9.—Mean illumination of desk No. 14 for eight classes of clouds. Arranged by months, September 17, 1923, to April 15, 1924, and by hour of observation, 9.40 a. m. to 3.40 p. m., Hagerstown, Md.

curves for either the outside illumination or the sky brightness (figs. 7 and 8). The curves showing hourly variation for these four desks (sections C and D of figs. 9, 10, 11, and 12) are not at all similar to the corresponding curves in Figures 7 and 8. The curves of seasonal variation (sections A and B of the figures) show some, though slight, similarity to the corresponding curves for the outside illumination and sky brightness; the dissimilarity in the seasonal curves, however, is not so pronounced as that in the hourly variation. The

greatest similarity which may be present in the curves for the inside and outside observations is that between the seasonal curves for sky brightness (fig. 8) and for the illumination on desks Nos. 17 and 23

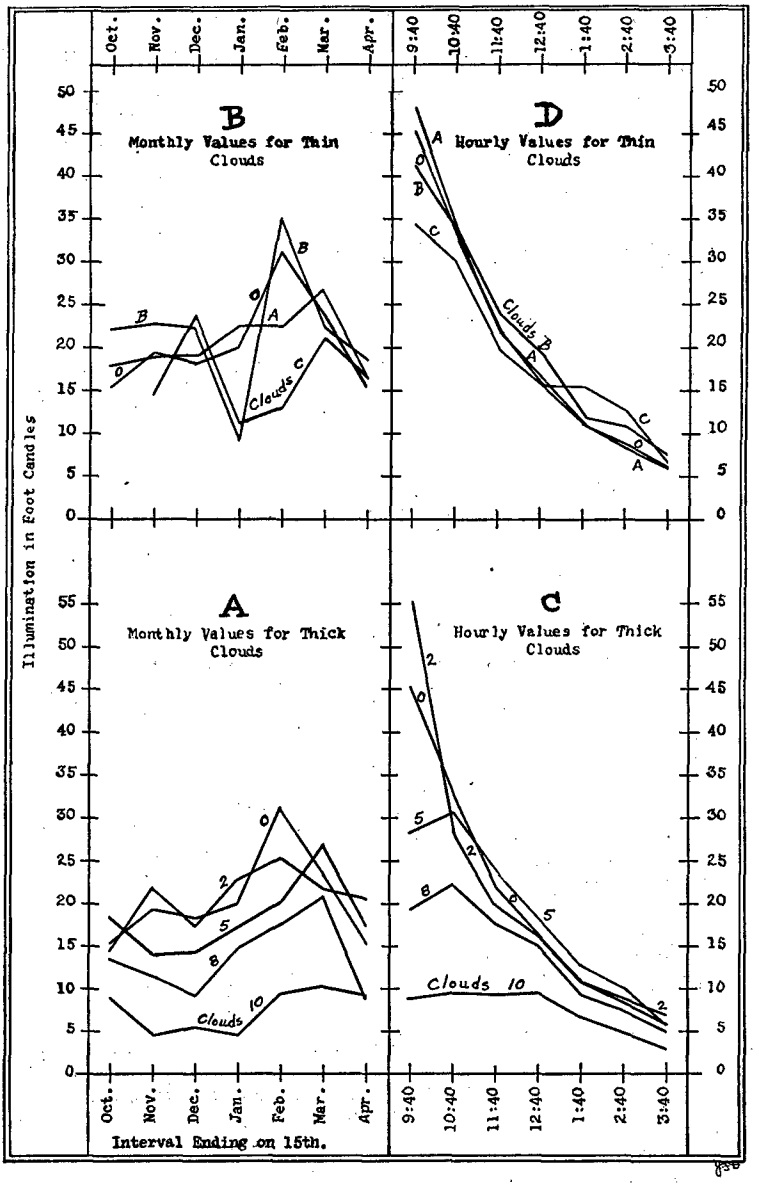


FIGURE 10.—Mean illumination of desk No. 20 for eight classes of clouds. Arranged by months, September 17, 1923, to April 15, 1924, and by hour of observation, 9.40 a. m. to 3.40 p. m., Hagerstown, Md.

near the windows (figs. 11 and 12). This same similarity was observed for the average seasonal curve in Public Health Bulletin 159 (see figs. 15 and 16, and p. 39 of that bulletin), obtained with the

values for all classes of clouds averaged together. It would seem, therefore, that at least for desks near the windows there is a fairly close relation of sky brightness to inside illumination.

The inside illumination has relatively much less seasonal variation than has the outside illumination. For the latter, as was noted

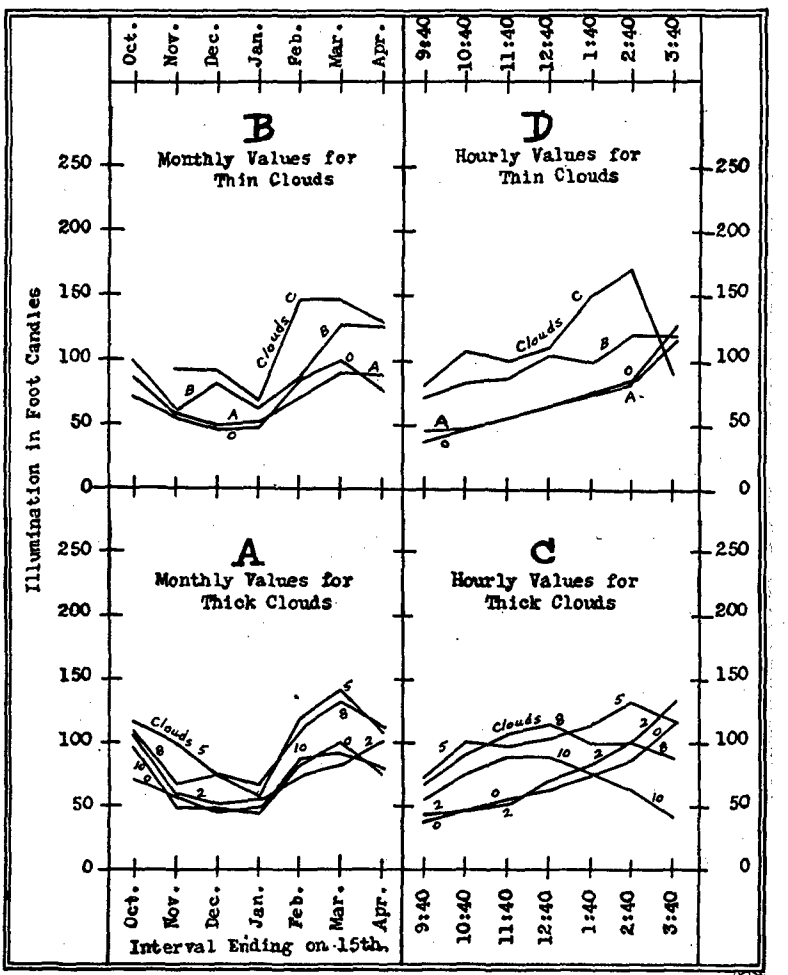


FIGURE 11.—Mean illumination of desk No. 17 for eight classes of clouds. Arranged by months, September 17, 1923, to April 15, 1924, and by hour of observation, 9.40 a. m. to 3.40 p. m., Hagerstown, Md.

before (sections A and B, fig. 7), there is a well-marked mid-winter minimum for each cloud class, but for the inside illumination there is very little change, especially for the desks far from the windows. In fact, for desk No. 14, with a northwest exposure (fig. 9), there is practically no variation at all for each individual cloud class for the

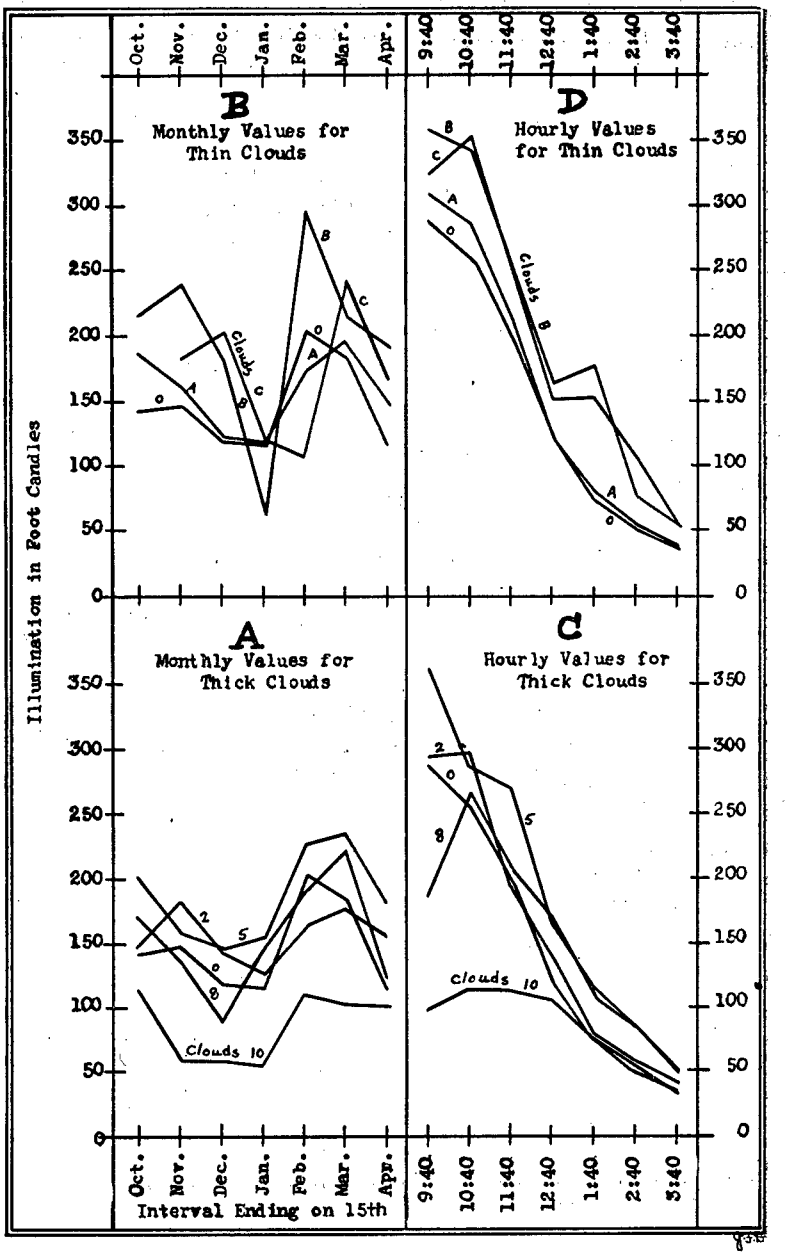


FIGURE 12.—Mean illumination of desk No. 23 for eight classes of clouds. Arranged by months, September 17, 1923, to April 15, 1924, and by hour of observation, 9.40 a. m. to 3.40 p. m., Hagerstown, Md.

fall and winter months, but during the spring months there is a small rise. The same thing is also largely true for desk No. 20 (fig. 10), which has a southeast exposure, but for this deak there is a larger vertical displacement between the lines of the graph (section A) than there is for desk No. 14. This variation between the lines representing the different classes of clouds shows that clouds have an important influence upon the illumination of this desk (No. 20). For the desks near the windows there is more seasonal variation evident, especially for the thick clouds, than there is for the desks far from the windows. Also, the desk with the northwest exposure (No. 17, fig. 11) has less variation between the cloud classes than has the desk with the southeast exposure (No. 23, fig. 12). Some of the variation, such as that manifest for class B clouds for January and February (figs. 10 and 12), is accidental and abnormal,[5] and not representative of the accuracy normally existing in the data.

An additional point which it seems well to note at this time is that among the seasonal curves for thick clouds the highest line for each desk usually is that for five-tenths clouds. Additional reference to this fact will be made later.

When the curves for the desks with the northwestern exposure (figs. 9 and 11) are compared with those for desks with a southeastern exposure (figs. 10 and 12), it is seen that for the former desks there is much less change in the actual illumination for each individual class of clouds than for the latter desks. This was previously noted in the monthly tabulations (sections A and B, figs. 9, 10, 11, and 12), but is especially true of the curves for the hourly tabulations. It is shown especially when sections C and D of Figures 9 and 11 are compared with the corresponding sections of Figures 10 and 12.

With further regard to the daily variation of the inside illumination as shown in sections C and D of the figures (9, 10, 11, and 12), it is to be noticed that the curves (desk No. 20 in Figure 10, sections C and D for example) are quite different from any other curves previously considered. The curves for this desk are quite high in the forenoon, especially for those lines representing few clouds. This is caused by sunlight either entering the room directly or falling obliquely upon the windows at these particular hours upon occasions

[5] The mean value of the illumination for class B clouds for desk No. 23 for the two monthly intervals January and February is shown in Table A and fig. 12, sec. B. By reference to Table 3 it is seen that during January there happened to be no observations with class B clouds at the 3 hours 9.40, 10.40, and 11.40 a. m. For this month, therefore, the high values normally existing for these 3 hours, such as are graphed in the left-hand half of fig. 12, sec. D, are not present. The mean obtained from the 4 values for the remaining 4 hours is therefore abnormally low as shown for January in fig. 12, sec, B. On the other hand, it is seen from Table 3 that during February there were no observations for class B clouds at 2.40 and 3.40 p. m. This would cause the mean of the remaining 5 hourly mean values to be somewhat high. It so happened also that such observations as were made during February with class B clouds were unusually high for the 3 hours 9.40, 10.40, and 11.40 a. m. This tends to exaggerate the high value resulting from the absence of observations at 2.40 and 3.40 p. m. The combined result is the very high value for class B clouds shown or February in fig. 12, sec. B.

when the clouds are few in number. These high values in the forenoon are due in part for this particular desk (No. 20 as contrasted with desk No. 14 on the northwest side of the building) to the peculiar orientation of the building and the southeast exposure of the room in which this desk is situated. For a room on the northwest side of the building the orientation tends to decrease the amount of direct sunlight which may fall on the windows. For this reason the curves of Figure 9, section C, for desk No. 14 do not rise in the afternoon, this being in contrast with the high values just noted in the forenoon in Figure 10, section C, for desk No. 20 on the southeast side of the building.

VARIATIONS CAUSED BY CLOUDS

In the preceding graphs (figs. 7 to 12, inclusive) it has been evident that a certain amount of variation in the illumination is caused by clouds. This is shown by the fact that the curves or lines for the different classes of clouds occur at different heights. If the illumination were independent of the clouds, all of the lines in each section of the figures would be superimposed. In order to show more precisely the nature of the variation of the illumination with the clouds, Figures 13 to 18 have been prepared. In each of these six figures the classes of clouds have been used to represent the horizontal or abscissa scale, the left-hand half of each figure being devoted to the thick clouds and the right-hand half to the thin clouds. In choosing the value of the abscissæ for the thin clouds, an attempt was made to plot them at the average of the values each included. Class A clouds were represented by a distance equal to that used for two-tenths thick clouds, class B by that corresponding to six-tenths thick clouds, and class C by the distance corresponding to ten-tenths thick clouds. The outside illumination is portrayed in Figure 13, the sky brightness in Figure 14, and the four desks, Nos. 14, 17, 20, and 23, in the four figures, 15, 16, 17, and 18, respectively.

A casual inspection of Figure 13 shows that the clouds, especially the thick ones, exert a large influence upon the outside illumination. The values for the thick clouds for each month (fig. 13, section A) and for each hour (fig. 13, section C) decrease materially as the number of clouds increases. For the thin clouds (fig. 13, sections B and D) the curves show a distinct downward trend as the number of clouds increases, but the decrease is not nearly so pronounced as in the case of the thick clouds. For the thick clouds, the decrease is so large that for ten-tenths clouds the mean illumination for seven months, October to April, is only 28 per cent of that for zero clouds for the same months (column 2, Table 4); but for the thin clouds, the decrease is a much smaller percentage, the mean of the six monthly values, November to April, for C clouds being 68 per cent of that for zero clouds. In

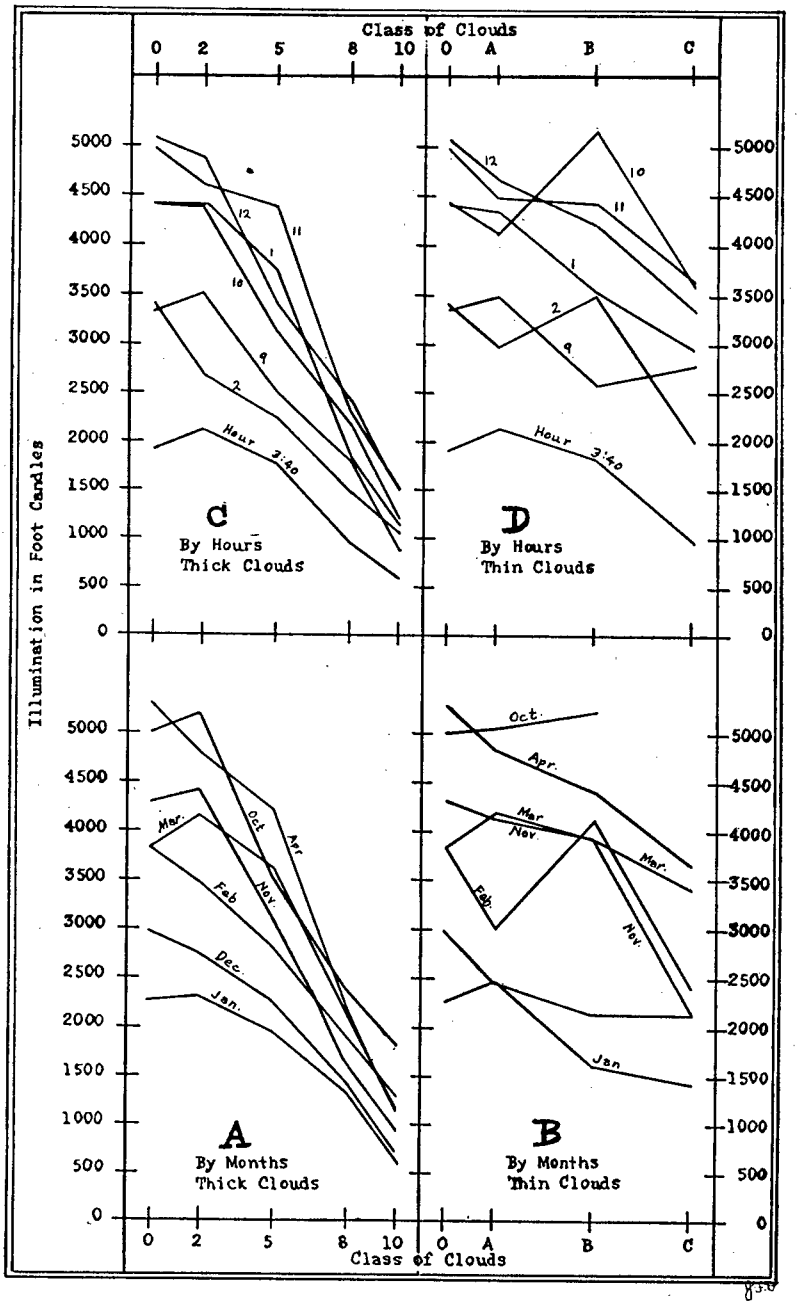


FIGURE 13.—Mean outside illumination for each month and hour of observation. Arranged for thick and thin clouds, 9.40 a. m. to 3.40 p. m., September 17, 1923, to April 15, 1924, Hagerstown, Md.

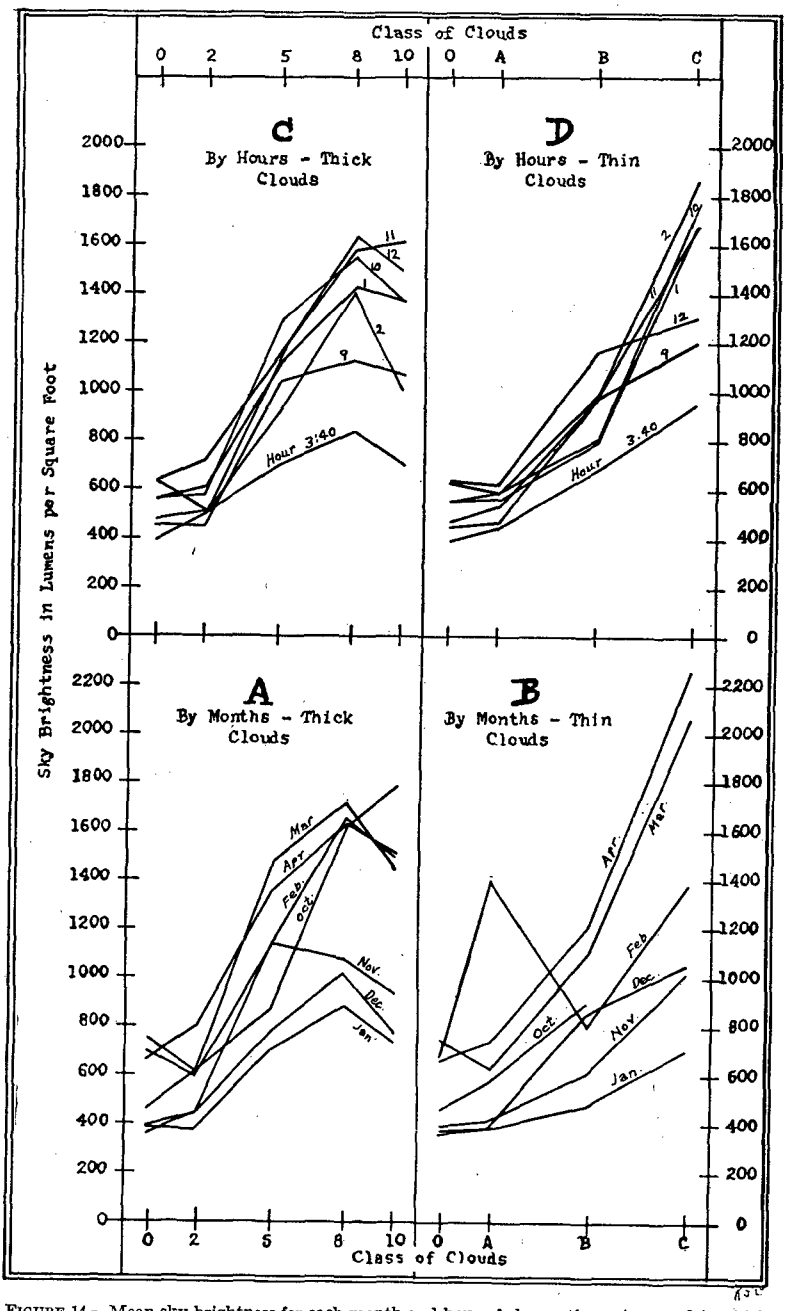


FIGURE 14.—Mean sky brightness for each month and hour of observation. Arranged for thick and thin clouds, 9.40 a. m. to 3.40 p. m., September 17, 1923, to April 15, 1924, Hagerstown, Md.

other words, for thick clouds the higher value is 2.52 times the lower value (that for ten-tenths clouds), while for thin clouds the higher value is 1.48 times the lower (class C clouds).

Figure 14 shows that a large increase in the sky brightness accompanies an increase in the number of clouds. This phenomenon is opposite to that just noticed for the outside illumination. The percentage increase in sky brightness is not as large for the thick clouds, however, as was the percentage decrease for the outside

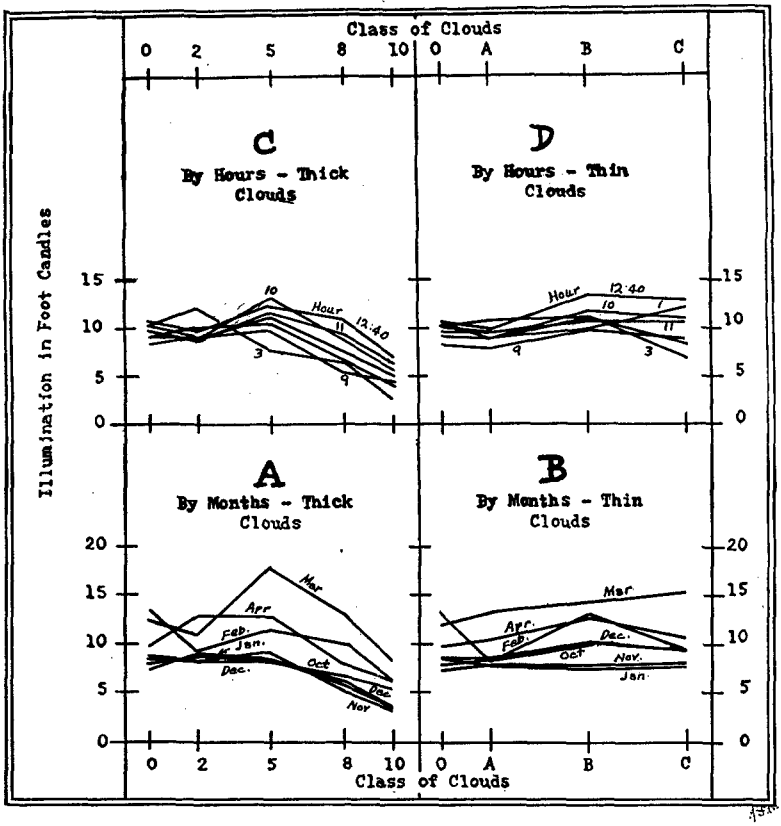


FIGURE 15.—Mean illumination of desk No. 14 for each month and hour of observation. Arranged for thick and thin clouds, 9.40 a. m. to 3.40 p. m., September 17, 1923, to April 15, 1924, Hagerstown, Md.

illumination; for the thin clouds the percentage increase is much larger. For the thick clouds, the mean for ten-tenths clouds for the seven months, October to April, is 2.36 times that for zero clouds, while for the thin clouds the mean for class C clouds for the six months, November to April, is 2.63 times that for zero clouds. These ratios of 2.36 and 2.63 are to be compared with the values 3.52 and 1.48, respectively, for the outside illumination, and confirms the earlier statement that for thick clouds the sky brightness changes less

with the clouds than does the outside illumination, but for thin clouds it changes more.

There is a feature common to the curves for thick clouds in both Figure 13 and Figure 14, which probably is significant. For the outside illumination for several of the months (fig. 13, section A) and several of the hours (fig. 13, section C) the values are higher at two-tenths clouds than for zero clouds, this occurring at the end of the

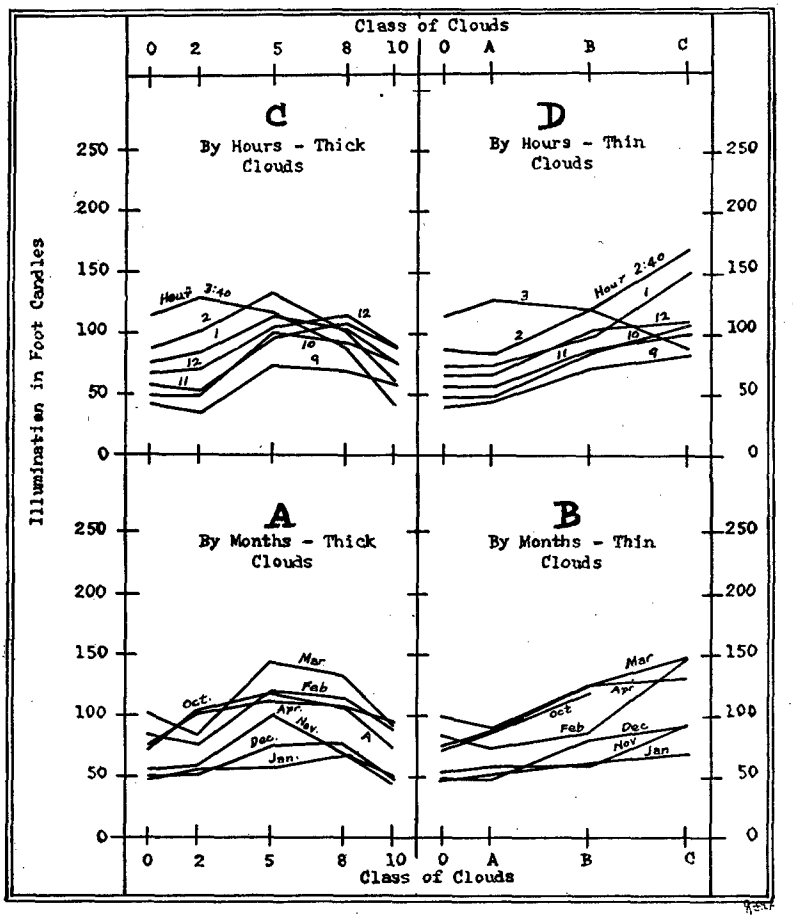


FIGURE 16.—Mean illumination of desk No. 17 for each month and hour of observation. Arranged for thick and thin clouds, 9.40 a. m. to 3.40 p. m., September 17, 1923, to April 15, 1924, Hagerstown, Md.

cloud scale corresponding to maximum outside illumination. In like manner, in Figure 14, sections A and C, at the end of the cloud scale corresponding to maximum sky brightness, the highest values are found for eight-tenths clouds rather than for ten-tenths clouds.

Another feature of these two figures (13 and 14) is that the curves for the outside illumination in Figure 13, especially those for the thick clouds, are concaved downward, while those for the sky brightness

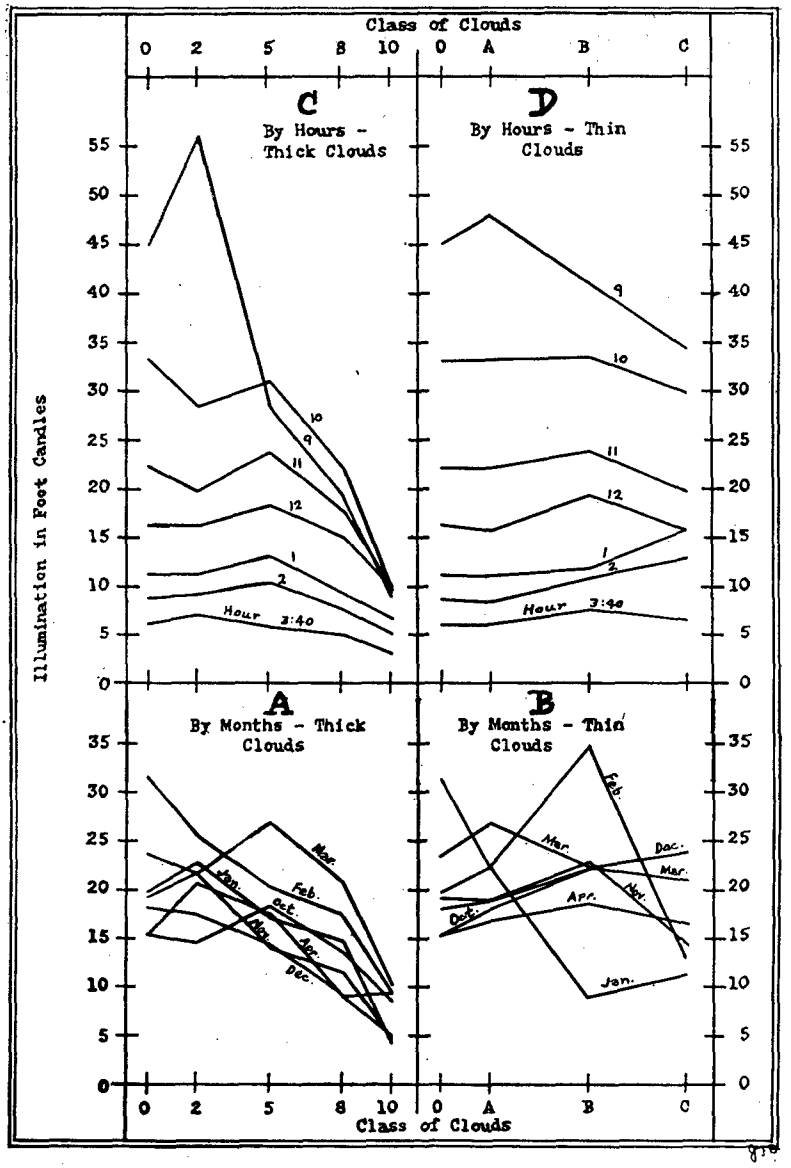


FIGURE 17.—Mean illumination of desk No. 20 for each month and hour of observation. Arranged for thick and thin clouds, 9.40 a. m. to 3.40 p. m., September 17, 1923, to April 15, 1924, Hagerstown, Md.

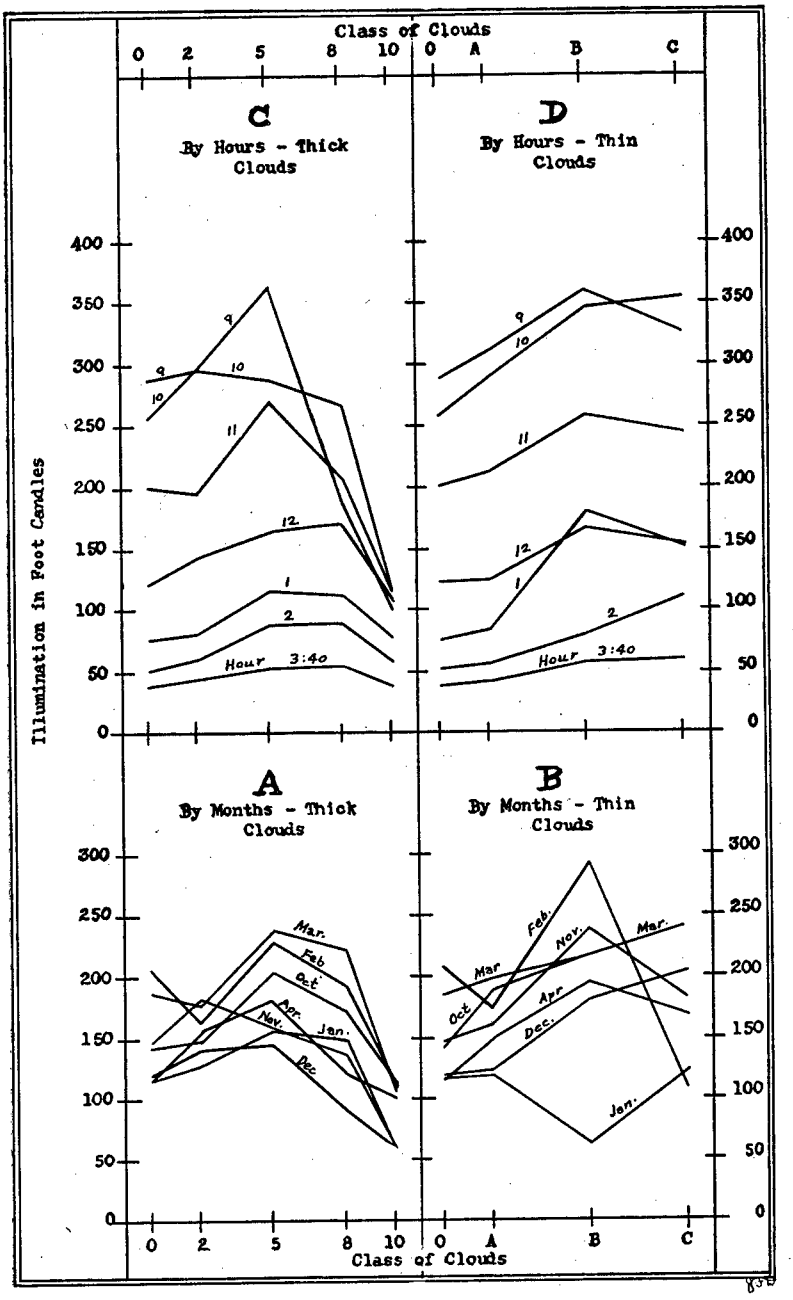


FIGURE 18.—Mean illumination of desk No. 23 for each month and hour of observation. Arranged for thick and thin clouds, 9.40 a. m. to 3.40 p. m., September 17, 1923, to April 15, 1924, Hagerstown, Md.

in Figure 14 are concaved upward, at least for the thin clouds and also for the thick clouds between the cloud classes of zero and eight-tenths.

Figures 15 and 16 give the values for the two desks Nos. 14 and 17 in room No. 204 on the northwest side of the building while Figures 17 and 18 are for the two desks Nos. 20 and 23 in room No. 207 with southeast exposure. The curves in Figure 15 are very much like those in Figure 16 although the latter is for a desk much closer to the windows. In like manner, Figures 17 and 18 are quite similar to each other. In general, the curves in Figures 15 and 16 do not rise or fall as they cross the page coincident with an increase in the number of clouds. There is a tendency, however, for the values for the thin clouds to rise and those for the thick clouds to fall after five-tenths clouds have been reached.

For desks Nos. 20 and 23 with a southeastern exposure, the outstanding characteristic as shown in Figures 17 and 18 is the large decrease in the illumination caused by the thick clouds during the forenoon hours 9, 10, and 11. For the thin clouds during the hours 9 and 10, there is an increase in the illumination with the clouds for desk No. 23 near the windows, but for desk No. 20 away from the window there is a decrease in the illumination. In sections C and D of Figures 17 and 18 the illumination for each successive hour occurs at a lower level, the level for 9.40 o'clock being about eight times that for 3.40 o'clock; for the two desks on the northwest side of the building, however, (figs. 15 and 16), the illumination for all of the various hours occurs at about the same level, the ratio of the level for 3.40 o'clock to that for 9.40 o'clock being not in excess of two. For the monthly values of the thin clouds portrayed in section B of Figures 17 and 18 there seems to be a distinct tendency for the illumination to increase as the clouds increase from class zero to class C.[6]

RELATIVE RELATIONSHIPS

An instructive analysis of the data for the inside illumination is obtained by expressing the illumination for each cloud classification and hour or month as a percentage of the illumination for the corresponding hour or month when the sky was cloudless. Such relative values have been prepared for four desks and have been designated "illumination relatives." [7] The desks for which these relatives have

[6] The abnormally low value for desk No. 23 for class B clouds during January and the unusually high values for February which were mentioned in the footnote on p. 26, are again portrayed in fig. 18, sec. B. They also appear for desk No. 20 in fig. 17, sec. B, but not to any marked extent for desks Nos. 14 and 17 in figs. 15, sec. B, and fig. 16, sec. B. The explanation is that probably some unusual condition of obscuration of the sun by clouds existed at the time the observations were made in room 207 for desks Nos. 20 and 23, or some error of unknown origin was committed in making the observations.

[7] These relatives are not the same as, and should not be confused with, the "daylight factor" or "inside-outside ratio" discussed in a later section of this bulletin and frequently referred to as "illumination ratio."

been prepared are Nos. 14, 20, 17, and 23, those previously selected for special consideration. The values are tabulated in Tables 8 and 9, the former giving the values computed from the means for each month, while Table 9 gives the values for each hour. They are shown graphically in the four figures, 19 to 22. Each of these figures includes the data for two desks; also, thick and thin clouds are shown separately for each, the left-hand half being for the thick clouds and the right-hand half for the thin clouds.

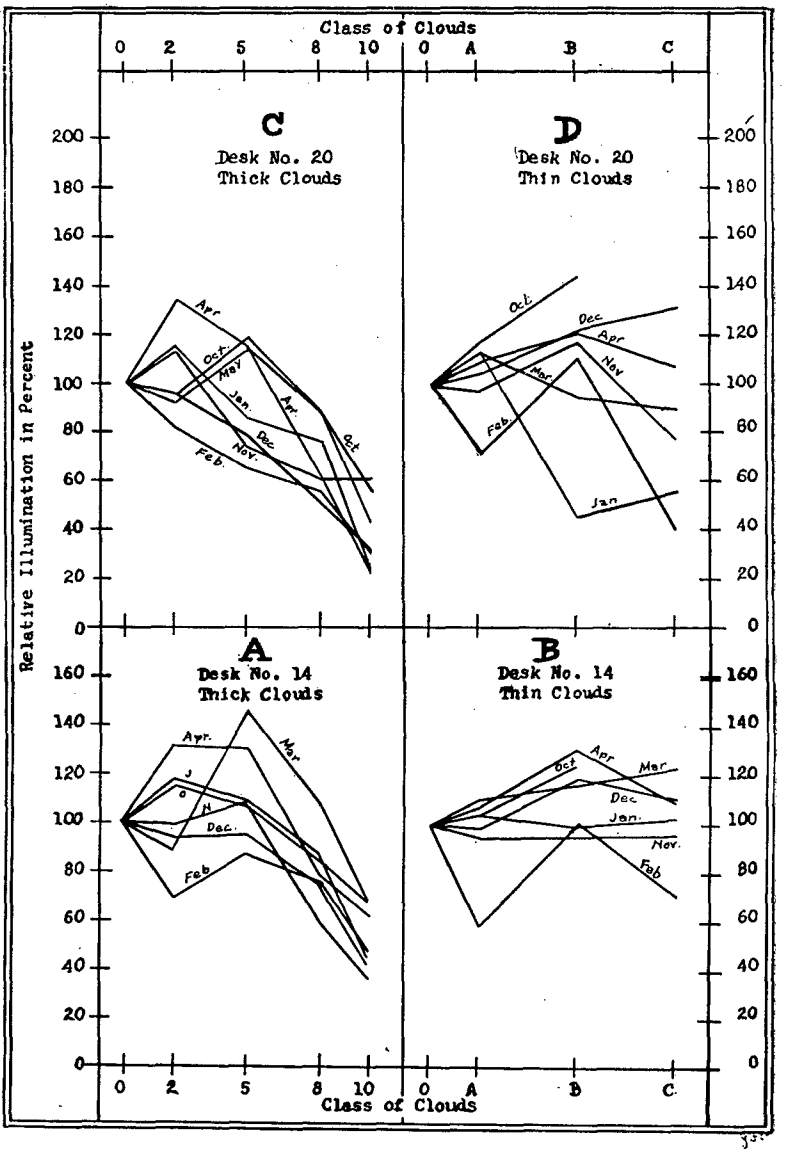


FIGURE 19.—Monthly values of illumination relatives for two school desks back from windows, arranged by classes of clouds. (Zero clouds=100.) Hagerstown, Md., September 17, 1923, to April 15, 1924

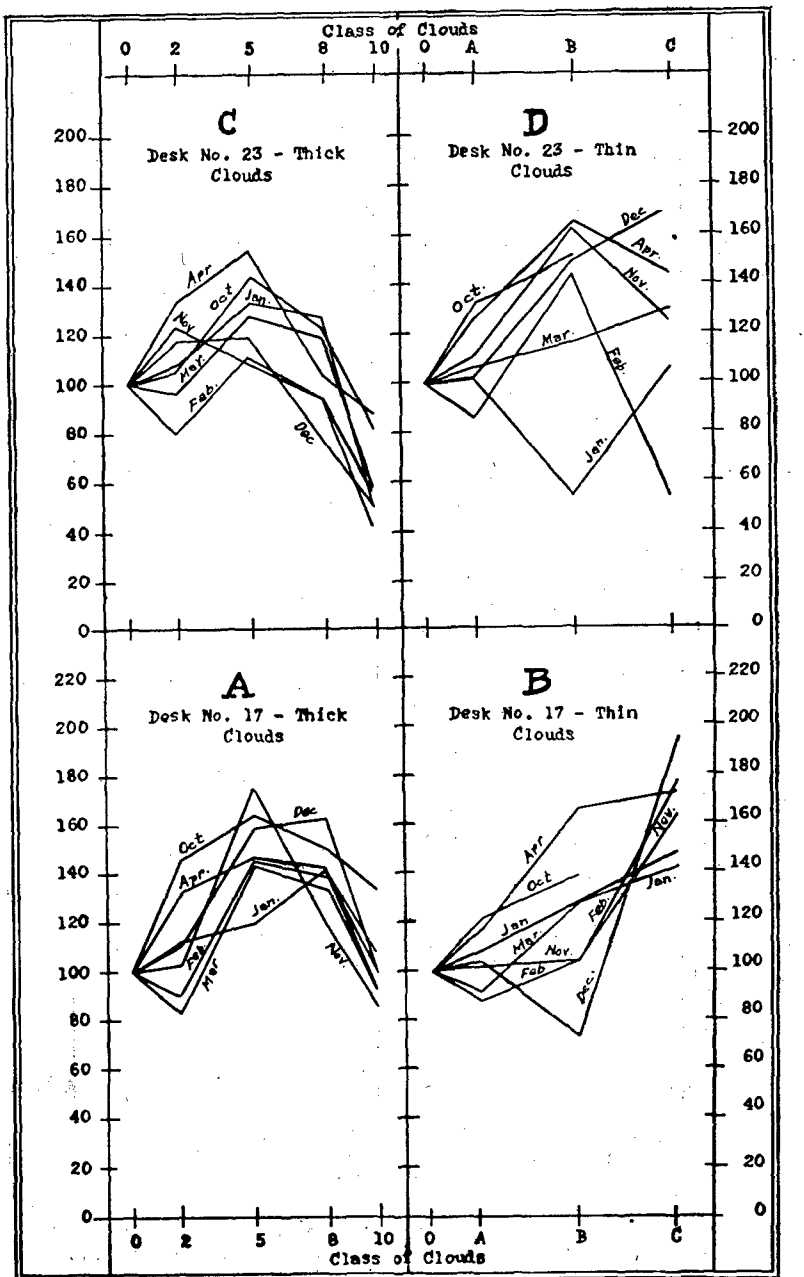


FIGURE 20.—Monthly values of illumination relatives for two school desks near the windows, arranged by classes of clouds. (Zero clouds=100.) Hagerstown, Md., September 17, 1923, to April 15, 1924

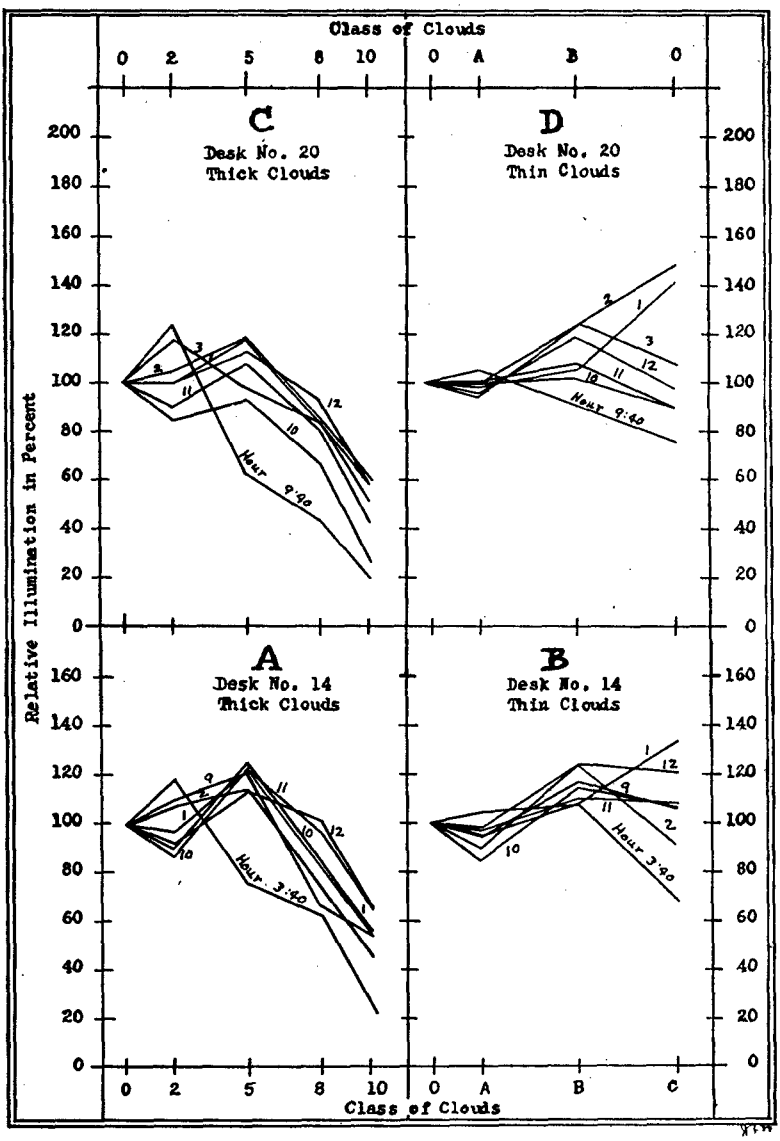


FIGURE 21.—Hourly values of illumination relatives for two school desks back from windows, arranged by classes of clouds. (Zero clouds=100.) Hagerstown, Md., September 17, 1923, to April 15, 1924

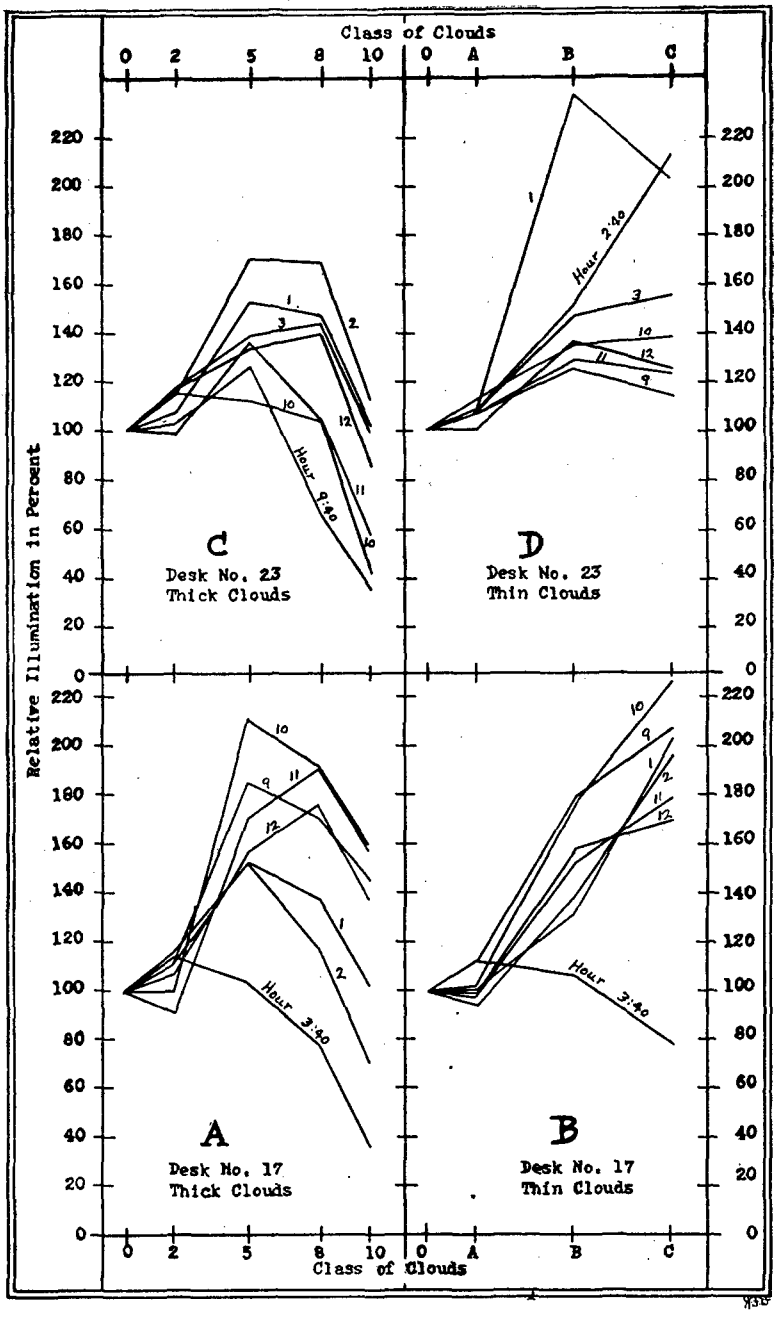


FIGURE 22.—Hourly values of illumination relatives for two school desks next to the windows, arranged by classes of clouds. (Zero clouds=100.) Hagerstown, Md., September 17, 1923, to April 15, 1924.

TABLE 8.—*Monthly illumination relatives for 4 school desks, arranged for each month and class of clouds, Hagerstown, Md., September 17, 1923, to April 15, 1924 (computed from Table A, appendix)*

Clouds	Mean (all months)	Ratio of illumination for each cloud class to illumination for zero clouds. (Zero clouds=100)						
		Oct.[1]	Nov.[1]	Dec.[1]	Jan.[1]	Feb.[1]	Mar.[1]	Apr.[1]
DESK NO. 14.—NORTHWEST EXPOSURE; BACK FROM WINDOWS								
0	100	100	100	100	100	100	100	100
2	102	114	99	94	117	69	89	131
5	111	106	108	95	109	87	145	130
8	81	85	59	74	87	76	107	79
10	52	67	36	41	43	47	68	62
A	97	104	95	99	104	59	110	107
B	112	125	95	119	99	100	117	131
C	102	----------	96	111	103	71	124	109
C/10	214	----------	267	269	241	150	182	177
DESK NO. 20.—SOUTHEAST EXPOSURE; BACK FROM WINDOWS								
0	100	100	100	100	100	100	100	100
2	104	95	113	95	115	81	92	134
5	93	119	73	78	86	64	114	115
8	68	88	60	51	75	55	88	59
10	38	57	23	30	24	30	43	60
A	104	118	98	105	113	71	114	110
B	108	144	118	123	46	111	95	121
C	84	----------	77	132	57	41	90	108
C/10	264	----------	329	442	238	139	208	180
DESK NO. 17.—NORTHWEST EXPOSURE; NEAR WINDOWS								
0	100	100	100	100	100	100	100	100
2	111	146	102	110	112	90	83	133
5	150	164	175	159	119	145	143	146
8	140	150	118	162	141	138	133	141
10	101	133	86	100	91	107	91	98
A	104	121	102	104	108	88	91	117
B	120	139	104	73	128	104	127	166
C	167	----------	163	196	142	178	148	173
C/10	174	----------	189	196	157	166	162	177
DESK NO. 23.—SOUTHEAST EXPOSURE; NEAR WINDOWS								
0	100	100	100	100	100	100	100	100
2	109	105	124	118	108	80	96	133
5	128	144	108	119	133	111	128	154
8	105	122	93	76	127	94	119	103
10	60	81	41	50	49	54	57	87
A	109	132	110	102	101	85	106	127
B	134	152	162	149	54	143	116	165
C	121	----------	125	170	105	53	130	144
C/10	226	----------	306	342	213	97	231	166

[1] Interval ending on the 15th day of the indicated month.

TABLE 9.—*Hourly illumination relatives for 4 school desks, arranged for each hour of observation and class of clouds, Hagerstown, Md., September 17, 1923, to April 15, 1924 (computed from Table B, appendix)*

Clouds	Mean, (6 hours only) [1]	Ratio of illumination for each cloud class to illumination for zero clouds. (Zero clouds=100)						
		9.40	10.40	11.40	12.40	1.40	2.40	3.40
DESK No. 14.—NORTHWEST EXPOSURE; BACK FROM WINDOWS								
0	100	100	100	100	100	100	100	100
2	97	110	87	90	91	97	108	118
5	120	121	126	121	113	122	114	75
8	84	66	84	97	101	83	74	62
10	57	54	54	65	65	57	46	26
A	93	94	85	97	90	95	98	105
B	116	117	115	110	124	108	124	108
C	111	106	106	108	120	133	91	69
C/10	196	198	195	167	183	234	200	259
DESK No. 20.—SOUTHEAST EXPOSURE; BACK FROM WINDOWS								
0	100	100	100	100	100	100	100	100
2	100	124	85	90	100	100	105	118
5	108	63	93	108	113	117	118	98
8	82	43	67	80	93	84	87	84
10	50	20	27	42	58	61	59	51
A	98	106	101	100	96	99	95	98
B	114	91	102	108	119	106	124	125
C	112	76	90	90	98	141	148	108
C/10	232	385	313	214	167	231	253	213
DESK No. 17.—NORTHWEST EXPOSURE; NEAR WINDOWS								
0	100	100	100	100	100	100	100	100
2	106	111	100	91	107	111	116	114
5	171	185	211	170	157	153	152	103
8	164	170	192	191	176	137	117	77
10	129	145	160	158	138	102	71	36
A	101	112	102	98	100	101	95	112
B	156	179	176	153	158	132	140	106
C	197	207	226	179	170	203	196	78
C/10	166	144	141	113	123	199	278	218
DESK No. 23.—SOUTHEAST EXPOSURE; NEAR WINDOWS								
0	100	100	100	100	100	100	100	100
2	112	102	115	98	117	107	115	117
5	140	126	112	136	133	153	170	138
8	134	65	103	104	139	147	168	143
10	84	35	45	57	88	102	111	98
A	107	107	112	106	100	108	107	108
B	155	124	134	128	135	237	151	147
C	158	113	137	122	124	202	211	154
C/10	201	327	304	214	141	198	191	156

[1] Omitting 3.40 p. m. for desks 14 and 17, and omitting 9.40 a. m. for desks 20 and 23.

The relatives for each hour are shown in Figures 21 and 22, the former including the two desks, Nos. 14 and 20, back from the windows, while Figure 22 covers desks Nos. 17 and 23 near the windows. In these graphs it is to be noticed that the lines at 9.40 a. m. for desks Nos. 20 and 23 (sections C and D of figs. 21 and 22), on the southeast side of the building, are considerably lower than those for the other hours of the day. This results from the high value of the illumination at that hour for zero clouds due to direct sunlight entering the room under these conditions. In like manner, for desks Nos. 14 and 17 (sections A and B of the figures), on the west side of the building, a similar phenomenon is observed at 3.40 p. m.

These four illustrations, and especially Figures 21 and 22 for the hourly values, emphasize the fact that the thin clouds produce an increase in the illumination over that observed for a cloudless sky. This is quite noticeably the case in Figure 22 for desks Nos. 17 and 23 situated near the windows. It is shown by the fact that the lines are above 100 per cent, the starting level. This condition of illumination in excess of that observed for zero clouds is also true for five-tenths thick clouds. It appears for both the monthly and hourly values for desks Nos. 17 and 23 in Figures 20 and 22. For the other two desks, Nos. 14 and 20, back from the windows, this is probably true if certain hourly values, such as 3.40 p. m. for desk No. 14 and 9.40 a. m. for desk No. 20, be omitted from consideration.

In order to analyze this characteristic more fully, using the hourly values, there was obtained for each class of clouds and for each desk a set of means which are shown in the second column of Table 9. In each case the tabular value for one particular hour was omitted from the mean; for those desks, Nos. 14 and 17, with a northwest exposure, the tabular values for 3.40 p. m. were omitted, while for desks Nos. 20 and 23, with a southeast exposure, the tabular values for 9.40 a. m. were omitted. In other words the omitted values are those for the hours at which direct sunlight could fall upon the windows of the respective rooms under consideration. The values in the second column of Table 9 are portrayed graphically in Figure 23; each quadrant of this graph is devoted to a single desk, and portrays the values for the thin clouds separately from those for the thick clouds. The arrangement of the four desks in this graph is the same as in Figures 21 and 22.

These four illustrations in Figure 23, two for rooms with a northwestern exposure and two for rooms with a southeastern exposure, show that, in general, there is an increase in the illumination in a room with an increase in the number of clouds either thick or thin, until about half the sky is covered. Beyond this point of cloudiness, it depends upon whether the desk in question is near the windows or back from the windows. For the latter case such as desks

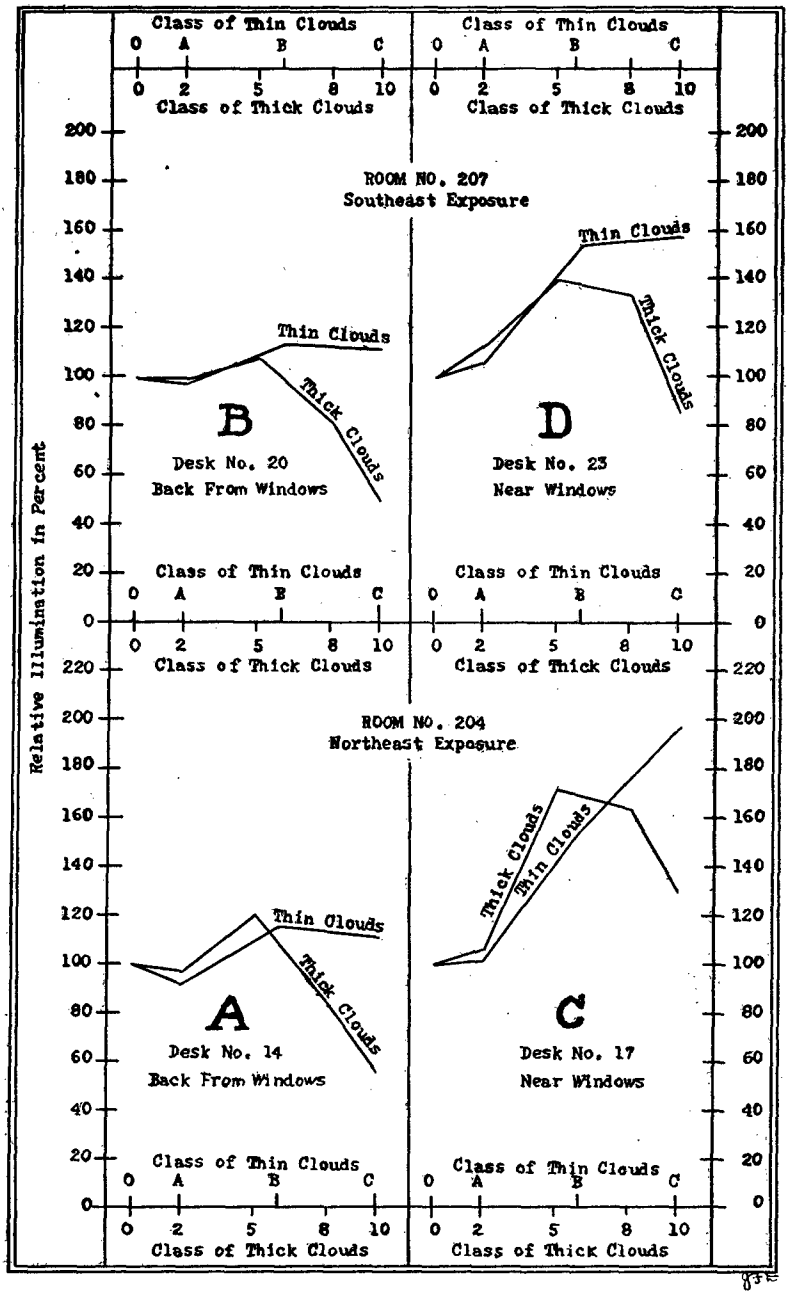


FIGURE 23.—Mean illumination relatives for thick and thin clouds for four desks. Based upon hourly values 9.40 a. m to 2.40 p. m. for desks Nos. 14 and 17, and 10.40 a. m. to 3.40 p. m. for desks Nos. 20 and 23, Hagerstown, Md., September 17, 1923, to April 15, 1924

Nos. 14 and 20, the maximum illumination is attained when the sky is half overcast without regard to whether the clouds be thick or thin; but for the two desks near the windows, Nos. 17 and 23, this is true only for the thick clouds, while for the thin clouds the illumination continues to increase until the sky is totally overcast (class C). For desks Nos. 14 and 20, the illumination when the sky is totally overcast by thin clouds is slightly less than when it is partially overcast only.

For the thick clouds, all four of the desks agree in that the maximum illumination corresponds to class five-tenths, the illumination for eight-tenths clouds is less than that for five-tenths, and that for ten-tenths is less than that for eight-tenths. Beginning at five-tenths clouds there is a continued and decided drop in the illumination until class ten-tenths is reached. The relative value of the illumination for ten-tenths clouds as compared with that for zero clouds, is quite dependent upon the location of the desk in question. For the two desks back from the windows, Nos. 14 and 20, the illumination for ten-tenths clouds is only about half (57 per cent and 50 per cent, respectively) that for zero clouds, while for the 2 desks near the windows, Nos. 17 and 23, that for ten-tenths clouds is approximately the same as for zero clouds, the actual tabular value for desk No. 17 being 129 per cent and that for desk No. 23 being 84 per cent.

There seems to be a remarkable fact in connection with the relative illumination for the two desks near the windows, Nos. 17 and 23, as shown in Figure 23, sections C and D. With only one exception, the value of the relative illumination for these two desks is above 100 per cent for every class of clouds either thick or thin, other than class 0. The one exception is for ten-tenths clouds for desk No. 23. For desk No. 17, after cloud class two-tenths and class A are passed, the illumination remained 29 per cent or more in excess of that for zero clouds. The author feels unable to hazard a guess as to whether these high relative values are due to the orientation of the building and the direction of exposure of the room, or the peculiar obscuration of the sky vault by the one large reasonably close tree. This tree cut off in winter much of the northern half of the sky vault which would have been visible if the tree had been absent, and in summer it cut off all of the northern half of the view from the windows. The peculiar reflection of the leaves of this elm tree may have much to do with this situation.

In general it can be stated that a large percentage of thin clouds is a benefit to the indoor illumination, while the reverse may or may not be true for thick clouds. It is true for thick clouds if the desk in question be near the windows, while if the desk be back from the windows it does not appear to be true and the clouds probably will result in less illumination but the loss may be small.

A further conclusion which can be drawn from Figure 23 is that 80 per cent or more of the illumination prevailing with a cloudless sky is still obtained until after thick clouds cover in excess of eight-tenths of the sky. This conclusion is based upon the means of the hourly relatives and when the low values for certain hours, 9.40 a. m. and 3.40 p. m., are omitted from the means for particular desks, depending upon the direction of their exposure. An inspection of the individual values for each hour graphed in Figures 21 and 22 shows that when the lines for the hours when direct sunlight gets into the room (9.40 a. m. for desks Nos. 20 and 23 and 3.40 p. m. for desks Nos. 14 and 17) are omitted from consideration this statement is still true for each individual line except for three of the values at eight-tenths clouds. Two of these are for desk No. 14 and one is for desk No. 20. However, when Figures 19 and 20, which give individual lines for each month are considered, the conclusion is not so generally applicable, the exceptions again occurring for the desks back from the windows (Nos. 14 and 20). The reason that in Figures 19 and 20 there are more exceptions is probably due to the fact that in these monthly values all of the seven hours are averaged together, and hence there is not omitted the more or less spurious values due to direct sunlight at 9.40 a. m. on desks with a southeastern exposure and at 3.40 p. m. on desks with a northwestern exposure. As a general conclusion, however, for desks reasonably near the windows and barring direct sunlight, the rule is quite valid that 80 per cent of the illumination of a cloudless sky is still retained until more than eight-tenths of the sky is covered by thick clouds.

In the interpretation of the data in Table 9 it is desirable that there be a graph with abscissæ represented by the hour of observation so that this graph can be compared with those previously presented (figs. 19 to 23) in which the abscissæ have been represented by the class of clouds. Such a graph is given in Figure 24. In this figure there is shown for each of four selected desks the ratio in per cent of the illumination for each hour at ten-tenths clouds to that for zero clouds, the ratio of the illumination for C clouds to that for zero clouds, and the ratio of the illumination for C clouds to that for ten-tenths clouds. In other words the graphs portray the values given in the fifth, eighth, and ninth lines for each desk in Table 9.

From an examination of Figure 24 it is to be seen that the lines representing the ratio of the illumination for ten-tenths clouds to that for zero clouds (the lines marked "10/0") show a decrease in the afternoon for desks Nos. 14 and 17 having a northwest exposure, and for desks Nos. 20 and 23 with southeast exposures there is an increase in the afternoon. The maximum is about three times the minimum of the curve for each of the desks except desk No. 17, for which the maximum is about four times the minimum. The curves

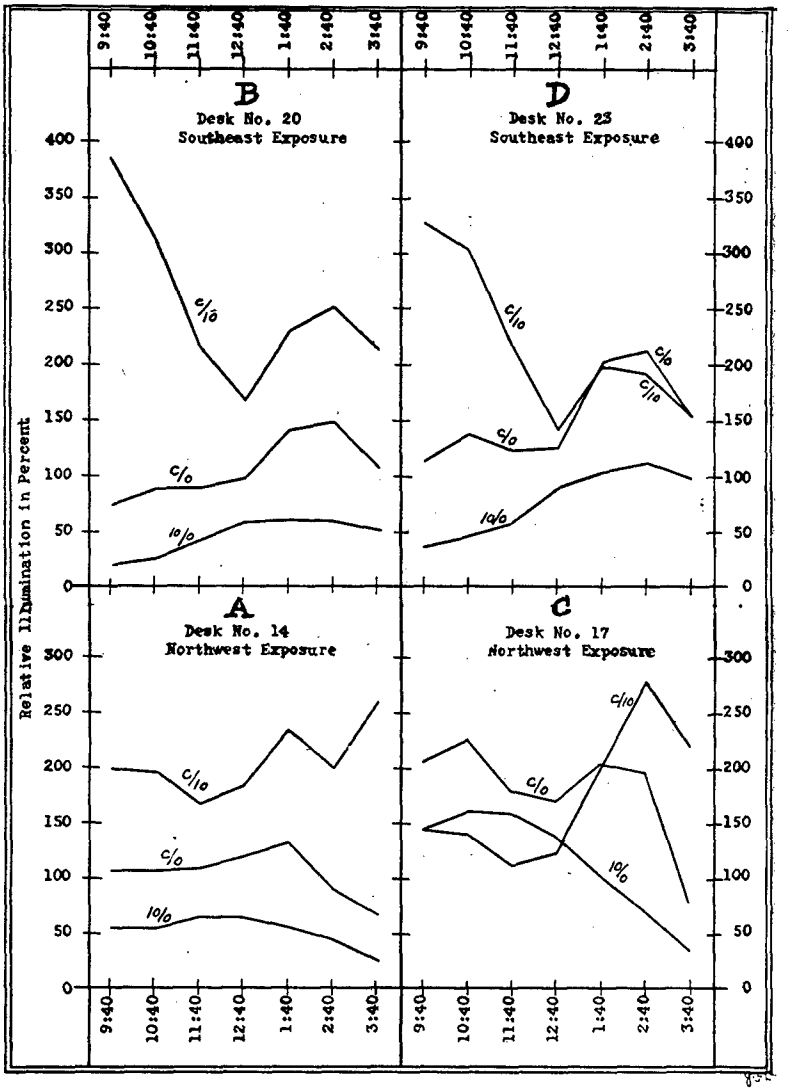


FIGURE 24.—Interrelationship ratios of three cloud classes, 0, 10, and C, for four desks, arranged for each hour of observation, 9.40 a. m. to 3.40 p. m., Hagerstown, Md., September 17, 1923, to April 15, 1924

C/0, being the ratio of the illumination for class C clouds to that for class zero clouds, have the same trend as that of the lines 10/0 for each respective desk; i.e., for the two desks with a northwestern exposure the trend is downward, while for the two desks with a southeastern exposure the trend is upward. The curves C/10, being the ratio of the illumination for class C clouds to that for ten-tenths clouds, are really ratios of the two curves c/0 and 10/0 just considered. A curve of this kind, C/10, measures the influence of ten-tenths thin clouds to that of ten-tenths thick clouds in their ability to increase or decrease the illumination. For each of these four desks the trend of the line C/10 is opposite to that for C/0 and 10/0. It is upward for desks Nos. 14 and 17 with a northwestern exposure and downward for desks Nos. 20 and 23 with a southeastern exposure. The values are all high, in the vicinity of 200 per cent, and in the forenoon hours desks Nos. 20 and 23 each have two hourly values in excess of 300 per cent.

A characteristic of each of the four curves C/10 that is not well marked and is somewhat masked by the effect of direction of exposure is a mid-day minimum in contrast to a possible early-morning or late-afternoon minimum depending upon the exposure direction. For desks Nos. 14 and 17 with a northwestern exposure the minimum occurs at 11.40 a. m., following which is a long afternoon rise to the maximum for the day; for desks Nos. 20 and 23 with a southeastern exposure the minimum occurs at 12.40 p. m., preceding which is a long forenoon decline from the early morning maximum for the day. Although this mid-day minimum is not well marked it seems quite probable that it is real.

RATIOS OF INDOOR MEASUREMENTS TO OUTDOOR MEASUREMENTS

DIFFICULTIES ENCOUNTERED IN ILLUMINATION SURVEYS

A difficulty often met in utilizing measurements of inside illumination is caused by the large and generally frequent changes of the illumination which occur under a great variety of conditions. The study under the heading, "The Influence of Clouds upon Illumination and Sky Brightness" of this bulletin (and also in Part II of Public Health Bulletin No. 159) identifies some of the causes of these changes and especially those which are ordinarily experienced in an illumination survey extending over only a few days. As previously pointed out, clouds passing over the sun cause great rapid changes in the illumination. Also for fixed atmospheric conditions, the illumination will vary with the time of the day, the nature of the variation depending upon the direction which is faced by the window of the room in which the observations are being made.

A method of avoiding the difficulties of this situation was discussed in the report of the departmental committee of the British Home Office [8] on Lighting in Factories and Work-Shops in 1915. By this method an attempt is made to eliminate these fluctuations as a source of disturbance in engineering work by expressing the illumination at the chosen point in the room as a ratio to that which would prevail at that point if the walls and roof of the building were removed, direct sunlight being excluded.[9] The committee referred to the inside-outside ratio as the "daylight factor" for the chosen point in the room. It was the opinion of this committee that "within limits a daylight factor tends to remain a constant quantity whatever the time of year or external meteorological conditions."

ILLUMINATION RATIO

The ideal conditions for making an experimental test of the constancy of the "daylight factor" would be to obtain observations of the outside illumination, excluding direct sunlight, simultaneously with the inside observations. The Hagerstown data were not obtained under such conditions, but were obtained with a determination of the total outside illumination, both from the sky and the sun, at the beginning and end of each hourly series of 24 inside measurements. The ratio obtained in this way may be called the "illumination ratio." This ratio must not be confused with the "daylight factor."

Some of the observations were rejected because of excessive cloud change and others (especially for this study of ratios) because of excessive changes in the outside illumination, the latter being the observations for which the change in the outside illumination between the first and second determinations of an hourly series was in excess of 25 per cent of the larger of the two values. About a fourth of the observations were rejected from the two causes, i. e., because of this excessive change in outside illumination and because of excessive changes in the number of clouds as heretofore explained on page 10 and shown in Table 3. It is believed that the remaining observations which were used will, on the average, prove to be more or less typical of results obtained from simultaneous determinations of the inside and outside illumination.

In the tables and graphs of the observations shown in this study of ratios, those values for cloud classes zero and ten-tenths are more

[8] First Report of the Departmental Committee on Lighting in Factories and Work-Shops, Home Office, 1915, Vol. I, p. 38.

[9] The fact that direct sunlight is to be excluded from the test plate is not specifically stated in the report, but is either stated or implied by various authors in subsequent publications, e. g., by A. K. Taylor in Journal of Scientific Instruments, Vol. I, p. 214, 1924; J. W. Walsh, Elementary Principles of Lighting and Photometry, 1923, pp. 152–155; and A. P. Notter, Illumination, 1911, pp. 247–248.

accurate than those for the other cloud classes. The number of observations for these two classes were about equal and comprised about one-half to two-thirds of all the observations used. Those for Class C were less numerous than those for zero or ten-tenths cloud classes, and were, therefore, the least accurate of the three.

RATIOS FREE FROM INSTRUMENTAL ERRORS

It seems desirable to point out that these inside-outside ratios are free from the influence of certain kinds of instrumental errors which, if present, would affect the values of the illumination itself. Such are errors in the assumed transmission of the daylight color filter, or a systematic error in the battery current at which the illuminometer working standard lamp was operated. Errors of these types would not affect the ratios, since they would affect the outside illumination and the inside illumination in the same relative amounts and therefore would disappear in the ratio.

VARIATIONS CAUSED BY CLOUDS

When the individual ratios computed for each observation in the indicated manner are averaged together for each class of clouds, the results are those given in the second column of Table C in the appendix. These average values for four selected desks, (Nos. 14, 17, 20, and 23), are shown in the form of a bar graph in Figure 25. In this figure as in the former bar graph, Figure 6, the results are analyzed by clouds alone.

It is evident that the illumination ratio is not constant under all cloud conditions. This is well shown in the bar graph by the fact that the ratio increases as the percentage of sky covered by clouds increases. This is particularly true for desks Nos. 17 and 23 near the windows. For example, for each of these two desks the value of the ratio during ten-tenths clouds is at least twice that existing for zero clouds. Furthermore, the tendency for the value of the ratio to increase with increasing cloudiness is true for thin clouds as well as for thick clouds, and is present for all four desks shown in the figure.

DIURNAL VARIATION

In the further analysis of the data, the individual ratios were sorted according to the month and the hour as well as the class of clouds. Averaging the value of the ratio for the nine monthly intervals, September 17, 1923, to June 15, 1924, there is obtained a mean value for each kind of clouds and for each of the seven hours at which observations were made. A casual inspection of the tabular values for any of the desks, such as Nos. 14 and 20, shows the validity of the statement previously made, viz, that the ratio is not constant. For each hour there is a change in the value of the illumination

ratio in passing from one cloud class to another. There also is a change throughout the day for each class of clouds. For desk No. 20 in a room with a southeast exposure, the ratio for zero clouds has the comparatively high value of 0.0134 at 9.40 a. m., but declines as the day advances until about noon or a little later when an approximately constant value of about 0.0030 or less is reached. For ten-

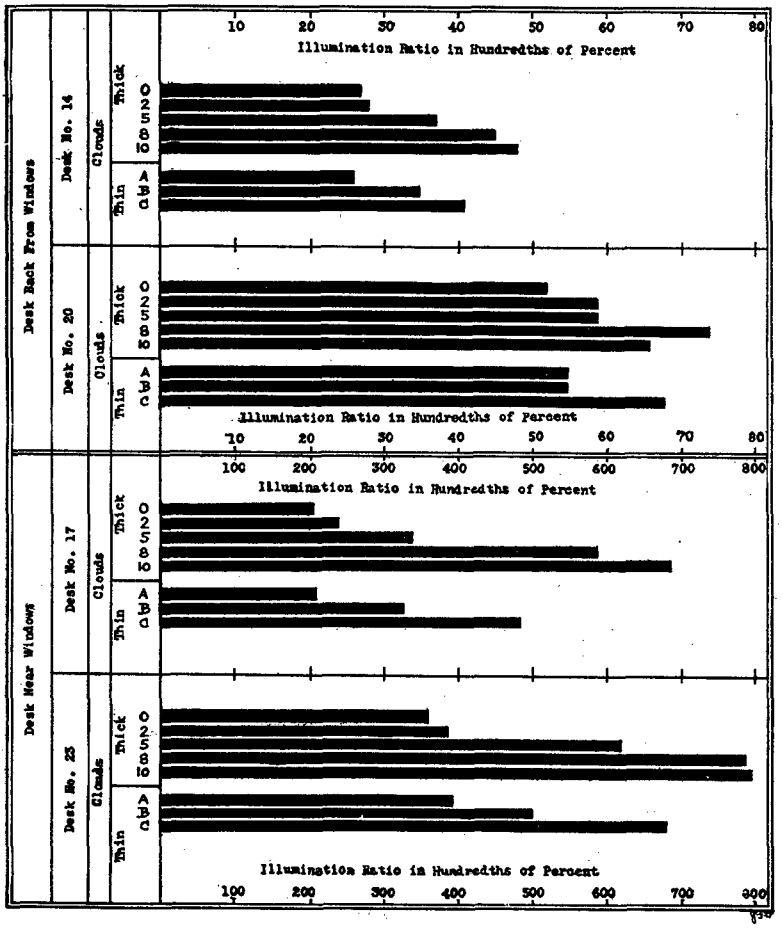


FIGURE 25.—Mean inside-outside illumination ratio for four school desks for each of eight classes of clouds. Hagerstown, Md., September 17, 1923, to June 15, 1924

tenths clouds, the change in the ratio is in the same direction, i. e., a decrease as the day advances, but the ratio decreases to a much less extent than it does for zero clouds; it starts at 9.40 a. m., with a value of 0.0080 and decreases to a value of about 0.0060 or more, this value being at least twice the value (approximately 0.0030 or less) noted as the afternoon mean for zero clouds. For the thin clouds, on the other hand, the change in the ratio is comparatively

large, being somewhat similar to the situation existing for zero clouds. In this case, however, the afternoon values are all considerably higher than those for zero clouds.

These changes in the ratio are shown graphically for four of the desks (Nos. 14, 20, 17, and 23) in Figure 26. In this figure and in those of a similar nature that follow, only four classes of the clouds have been included, those being 0, 5, and 10 tenths, and C clouds. The values shown in Figure 26 were taken from Table C in the appendix.

The left-hand half of Figure 26 (sections A and C) is devoted to desks Nos. 14 and 17 with a northwestern exposure; the right-hand half is used for desks Nos. 20 and 23, with a southeastern exposure. For the latter desks it is to be seen that the lines run quite high during the forenoon hours. On the other hand, for desks Nos. 14 and 17 (fig. 26, sections A and C) the highest values occur in the late afternoon. The rooms with a southeastern exposure have high values of the ratio in the forenoon, and the rooms with a northwestern exposure have the high values in the afternoon. These high values are obviously associated with direct sunlight on the windows of the respective rooms. Because of the orientation of the building, the angle of incidence of the sunlight in the late afternoon on the northwest wall is much less than it is for the early forenoon hours on the southeast wall. For this reason the values of the ratio do not rise as high in the afternoon for desks 14 and 17 as in the forenoon for desks 20 and 23.

SEASONAL VARIATION

For the purpose of determining a seasonal trend by comparing monthly means for each cloud class, it did not appear proper to obtain the mean for all hours of the day because of the unusually high value for those hours at which there was direct sunlight in the room or on the windows. Accordingly, in computing the means for each month only the afternoon observations, from 12.40 p. m. to 3.40 p. m., were used for those desks having an eastern exposure (such as desks Nos. 20 and 23) when there was relatively little change in the ratio; and for desks on the other side of the building (such as Nos. 14 and 17) only the forenoon observations, from 9.40 a. m., to 1.40 p. m., were used. The values for each of the eight classes of clouds show a well defined seasonal change with a maximum at the winter season. A graphic representation of mean values for each kind of clouds and for each of the nine months for each of the 24 desks for the four cloud classes 0, 5, 10, and C is shown in Figure 27, the values being taken from Table D in the appendix.

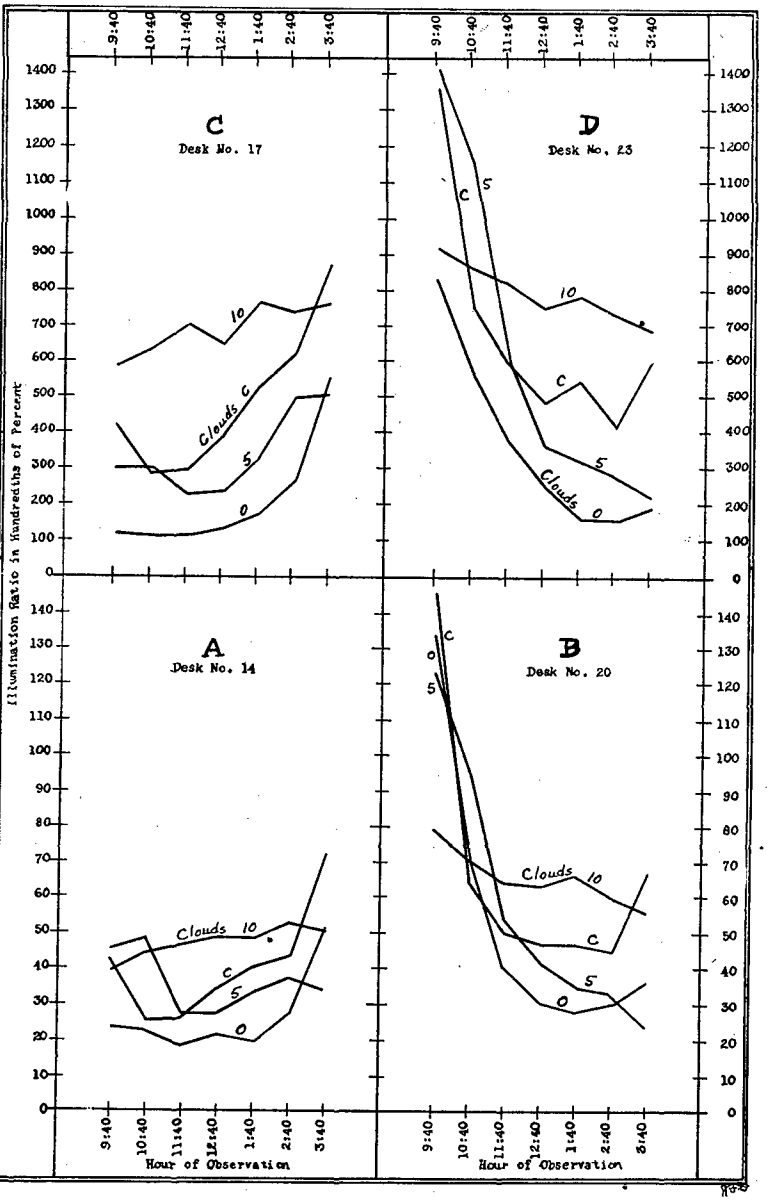


FIGURE 26.—Hourly values of the "illumination ratio" (means of nine monthly values) for four school desks for four specially chosen classes of clouds. Arranged by hour of observation, 9.40 a. m. to 3.40 p. m., Hagerstown, Md., September 17, 1923, to June 15, 1924

In general, the line graph for each cloud class follows a fairly definite trend in which all four desks concur more or less closely.[10]

That there is a seasonal change in the illumination ratio, there seems to be no doubt, the primary characteristic being a winter maximum. One of the causes of this may be the falling of the leaves from the trees surrounding the building. Dropping of the leaves in the fall which would admit more light and produce a higher value of the ratio, is coincident with the maximum in the seasonal curves of the ratio, and hence may be one of the major causes of the seasonal changes. It is believed, however, that this is not the only cause of the seasonal change, since the curves in Figure 27 show considerable gradual change during the interval November 1 to April 1 which represents approximately the period when the leaves were absent.

With further reference to Figures 26 and 27, in Figure 26 the graphs have been plotted with the hour of the day as abscissæ, and in Figure 27 with the month of the year as abscissæ. If the ratio were constant, these lines would tend to be straight and horizontal. The fact that these lines are not straight and horizontal shows (omitting the possibility of chance variation) that on the average the inside-outside illumination ratio is not constant so far as these two factors are concerned. A third factor of variation is shown by the differences in the height of the lines. If the ratio were constant for all classes of clouds, the four lines in each quadrant of the two figures would be superimposed, i. e., identical.

Quantitatively these changes are not negligible. In Figure 27 it may be seen that the value of the ratio for a given month at the time of 10 tenths clouds is generally at least twice that existing when there were no clouds. Also, for any line of the chart corresponding to a fixed condition of cloudiness, the value of the ratio in winter is at least twice that of early fall or late spring. Furthermore, when changes in both cloud condition and season are taken into consideration, the percentage change in the ratio is much larger; for example in Figure 27, section B, the maximum value of the illumination ratio for desk No. 20 for 10 tenths clouds in March is exactly seven times the minimum value for zero clouds in June. For desk No. 14, the other desk back from the windows, the corresponding relative value is 6.3, while for the two desks near the windows (Nos. 17 and 23) the values are somewhat larger, being 9.8 and 11.2, respectively. The values of the illumination ratio from which these numbers were computed are

[10] To this, however, there is one conspicuous exception in class C clouds for January for desk No. 20 (fig. 27, sec. B) which has a value of 0.0104, or about twice as large as would normally be expected from the other curves. The fact that this value is so high appears to be purely accidental, it being based on only one observation. This value of 0.0104 is supposed to be the mean of the four hourly values from 12.40 p. m. to 3.40 p. m., but for this particular month and class of clouds there was a value for only one hour, 3.40 p. m. The situation is further affected by the fact that this one hourly value, 0.0104, was an unusually large one and, because it stood alone, could not be reduced in size by being averaged with the three other values for the other three hours normally included in the average.

averages for a month; individual values would of course show even greater variation. The same general conclusion that the value of the illumination ratio is many times larger for ten-tenths clouds than for zero clouds may also be drawn from Figure 26 when the changes

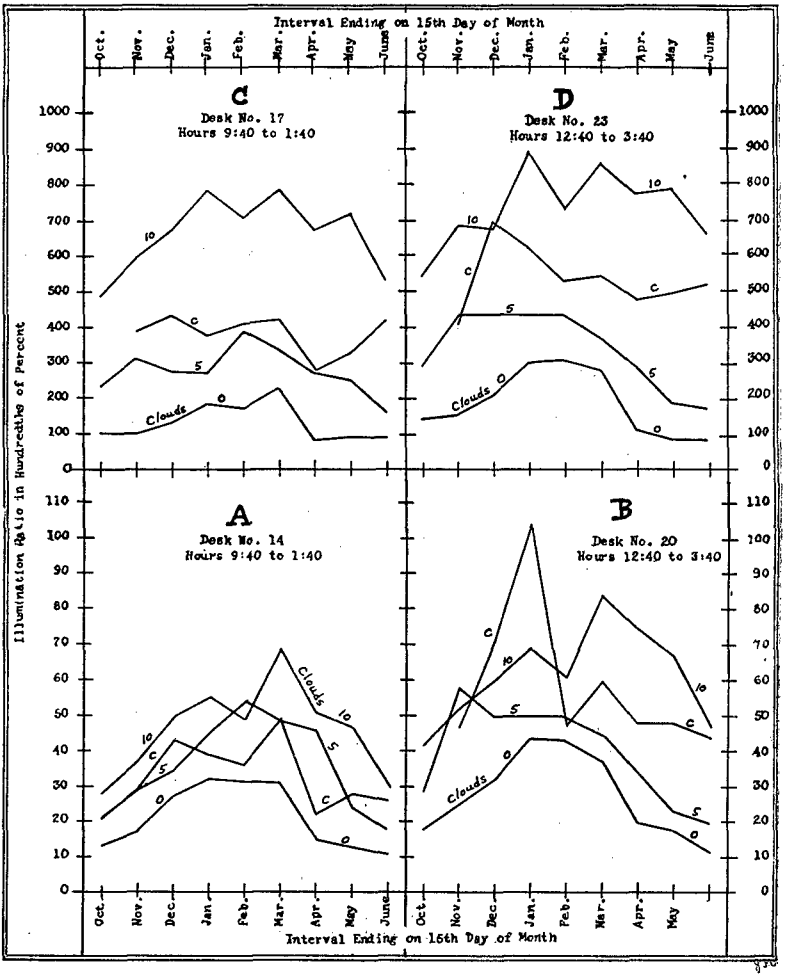


FIGURE 27.—Monthly values of the "illumination ratio" (means of values for only certain indicated hours) for four school desks for four specially chosen classes of clouds. Arranged by months, September 17, 1923, to June 15, 1924, Hagerstown, Md.

with clouds and the hour of the day are taken jointly into consideration.

In order to provide a better picture of the effect of clouds upon the illumination ratio, two additional graphs, Figures 28 and 29, have been prepared. In these illustrations the abscissæ represent the cloud classes. Both the thick and thin clouds are provided for separately,

the left-hand half of each figure being for the thick clouds while the right-hand half is for the thin clouds. These two figures represent the data for desks Nos. 14 and 20, respectively, both of which are situated back from the windows. The lower half of each figure gives a line showing the various values of the illumination ratio for each of the nine months covered by the observations, and the upper half

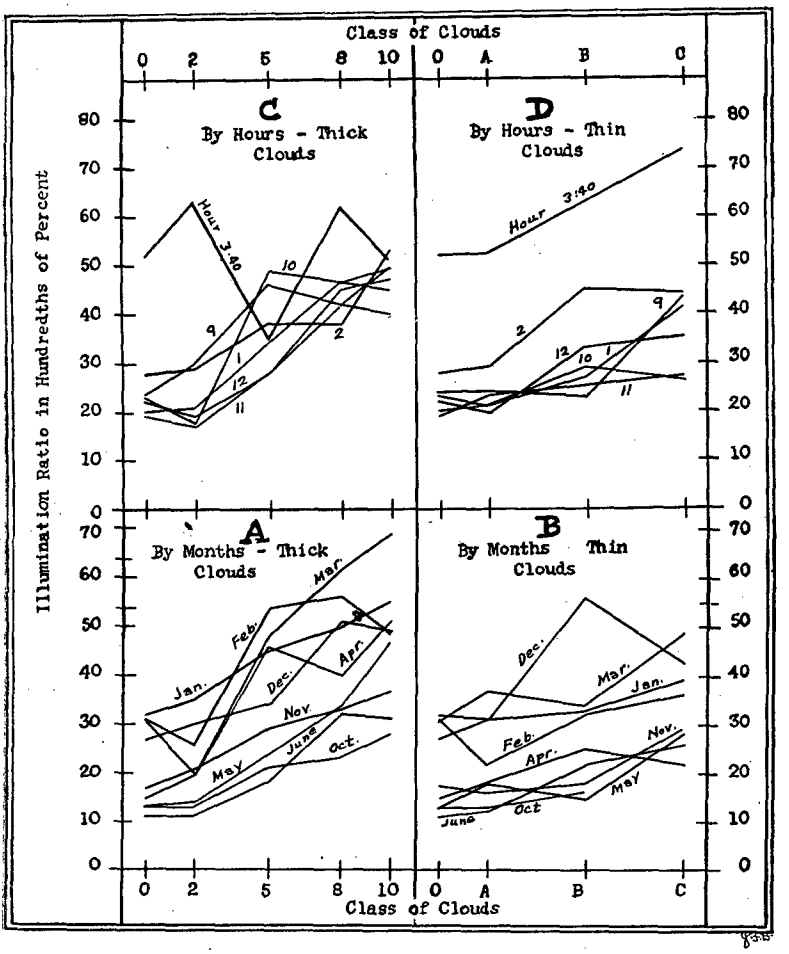


FIGURE 28.—Mean "illumination ratio" of desk No. 14 for each month and hour of observation. Arranged for thick and thin clouds, 9.40 a. m. to 3.40 p. m., September 17, 1923, to June 15, 1924, Hagerstown, Md.

shows a line for each of the seven hours of the day during which observations were made.

In every section of these two graphs, every line except those for the two hours 9.40 and 10.40 a. m. for desk No. 20 (fig. 29) shows a marked increase in the illumination ratio corresponding to a larger portion of the sky being covered by clouds. This is true for thin

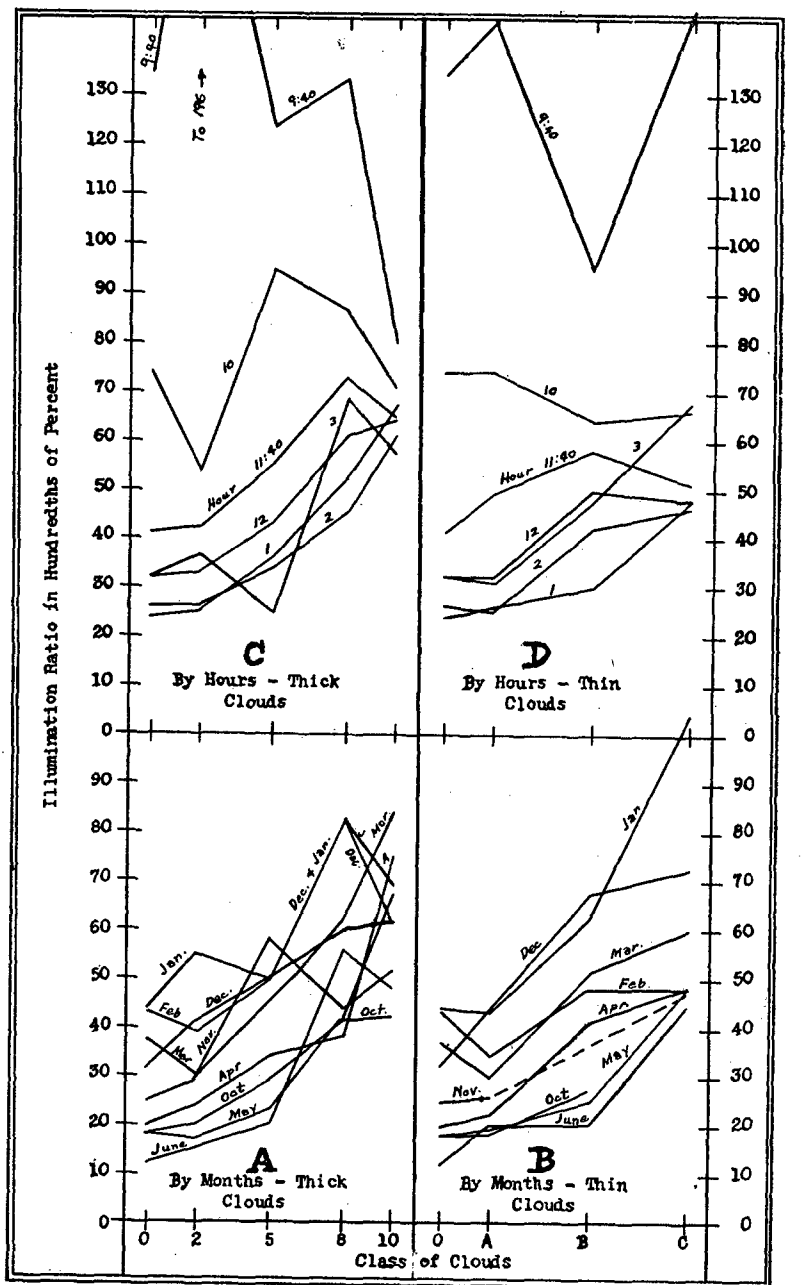


FIGURE 29.—Mean "illumination ratio" of desk No. 20 for each month and hour of observation. Arranged for thick and thin clouds, 9.40 a. m. to 3.40 p. m., September 17, 1923, to June 15, 1924, Hagerstown, Md.

clouds as well as for thick ones. The general trend is well marked in every case. In Figure 29, section A, for example, the mean of the nine monthly values for zero clouds is 0.0028 and the corresponding value for ten-tenths clouds is 0.0062, the change of 0.0034 being 121 per cent of the value for zero clouds. The erratic course taken by the curves for hours 9.40 and 10.40 a. m. for desk No. 20 (fig. 29) is, of course, due to the familiar effect of direct sunlight on the windows at the time of few clouds. Graphs similar to Figures 28 and 29, but for desks Nos. 17 and 23, near the windows, were not included, as they are quite similar to the two given. The primary difference is that the increase in the size of the illumination ratio coincident with an increase in the extent of cloudiness is much larger for desks near the windows (Nos. 17 and 23) than is shown in Figures 28 and 29 for desks away from the windows (Nos. 14 and 20).

SKY BRIGHTNESS RATIO

The brightness of the portion of the sky visible from the interior of a room has an important bearing upon the indoor illumination. For this reason it is interesting to compute a ratio between the indoor illumination and the brightness of the sky. In this study the brightness of the sky was measured at a spot in the sky opposite the sun and 90° from it, except under certain conditions which are discussed on page 7 of this bulletin.

This ratio was computed for each desk between the individual values of the indoor illumination expressed in foot-candles and the brightness of the sky expressed in lumens per square foot. We have called it the "sky brightness ratio" in contrast to the "illumination ratio." The sky brightness ratio is a quantity similar in character to the "daylight factor" referred to on page 48.

PROCEDURE

Throughout this section on the "sky brightness ratio" the procedure followed in preparing the data and in its analysis was closely parallel to that followed in the study on the "illumination ratio." In computing the sky brightness ratios, the value used to represent the sky brightness was the mean of the two sky brightness measurements made immediately following the two determinations of the outside illumination at the beginning and end of each hourly series of observations. This procedure (similar to that followed in computing the values of the illumination ratio) was believed to be more advisable than that of obtaining values corresponding to the indoor measurements for each of the 24 desks by interpolating between the two beginning and ending sky brightness values of the hourly series. However, in this case (sky brightness) there probably would be more

justification for the use of interpolation than there was in the case of the outside illumination; this is true because the average brightness of the sky is probably less changeable over a period of about 15 minutes duration than is the outside illumination. On the advisability of interpolation, however, there is some doubt, because for any particular desk the effective sky brightness is the brightness of that portion of the sky visible from that desk, and that brightness could easily change in a short time by the appearance or disappearance of a cloud of appreciable size in that portion of the sky.

As in the case of the "illumination ratio," this procedure of using the mean of the two outside values was believed to be justifiable for average results because of the comparatively large number of observations and because the poorer of the observations were rejected. As heretofore, some of the observations were rejected because of excessive changes in the extent of cloudiness; others were rejected because of excessive change between the two values for the sky brightness, these being the observations for which the change in the sky brightness between the first and second determinations of an hourly series was in excess of 25 per cent of the larger of the two values. The number of observations rejected in this work [11] was about the same as those rejected in the case of the "illumination ratio," but the particular observations rejected were not always the same in the two cases. It is believed, as heretofore, that the remaining observations which were used will on the average prove to be more or less typical of results which would be obtained from simultaneous determinations of the inside illumination and the brightness of the sky.

VARIATIONS CAUSED BY CLOUDS

The individual ratios between the inside illumination for each desk and the sky brightness were computed in the indicated manner and averaged together for each class of clouds. The values for four selected desks (Nos. 14, 17, 20, and 23), taken from Table E in the appendix, are shown as a bar graph in Figure 30. In this figure, as in the former bar graphs, Figures 6 and 25, the results shown were obtained by analyzing the data by clouds alone.

It is evident that the "sky brightness ratio" similar to the "illumination ratio" is not constant under all cloud conditions. The bars representing the value of the sky brightness ratio under different degrees of cloudiness are not the same length. As the degree of cloudiness increases, the bars become materially shorter indicating a large decrease in the value of the ratio. For these four desks the value of the ratio at the time of a cloudless sky averages 4.4 times that

[11] As in the case of the "illumination ratio," it seemed unnecessary to give another table similar to Table 3 which would show the number of observations for each class of clouds and hour and month used in computing the "sky brightness ratio."

existing when the sky is totally overcast with thick clouds, i. e., ten-tenths. As for thin clouds, the change is well marked and the tendency is the same as was noticed for thick clouds.

DIURNAL AND SEASONAL VARIATIONS

In addition to an analysis according to clouds, these sky brightness ratios were classified and averaged according to the month and the

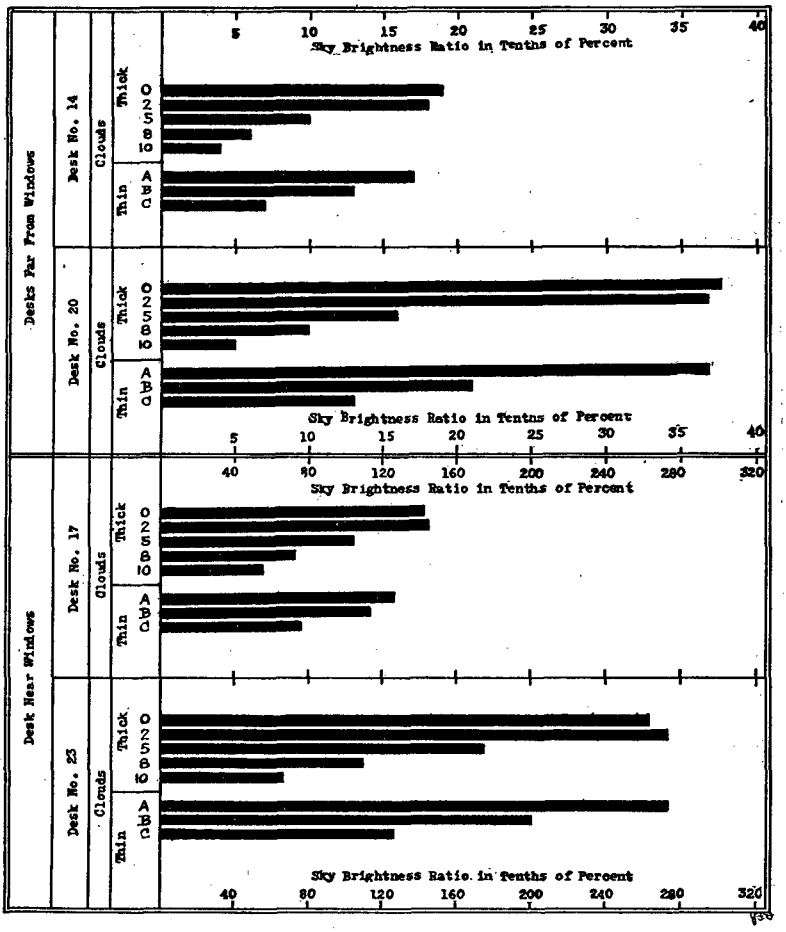


FIGURE 30.—Mean "sky brightness ratio" for four school desks for each of eight classes of clouds. Hagerstown, Md., September 17, 1923, to June 15, 1924

hour. Each of these values was computed in the same manner as were those for the illumination ratio; that is, the hourly means are the averages of nine monthly values, and the monthly means are the averages of the values for the four or five hours when the room is free from direct sunlight. The hourly values of the sky brightness ratio for four desks are shown graphically in Figure 31. This figure is

similar to Figure 26 for the illumination ratio. The hour of observation is represented by the abscissa, and there is given a curve for each

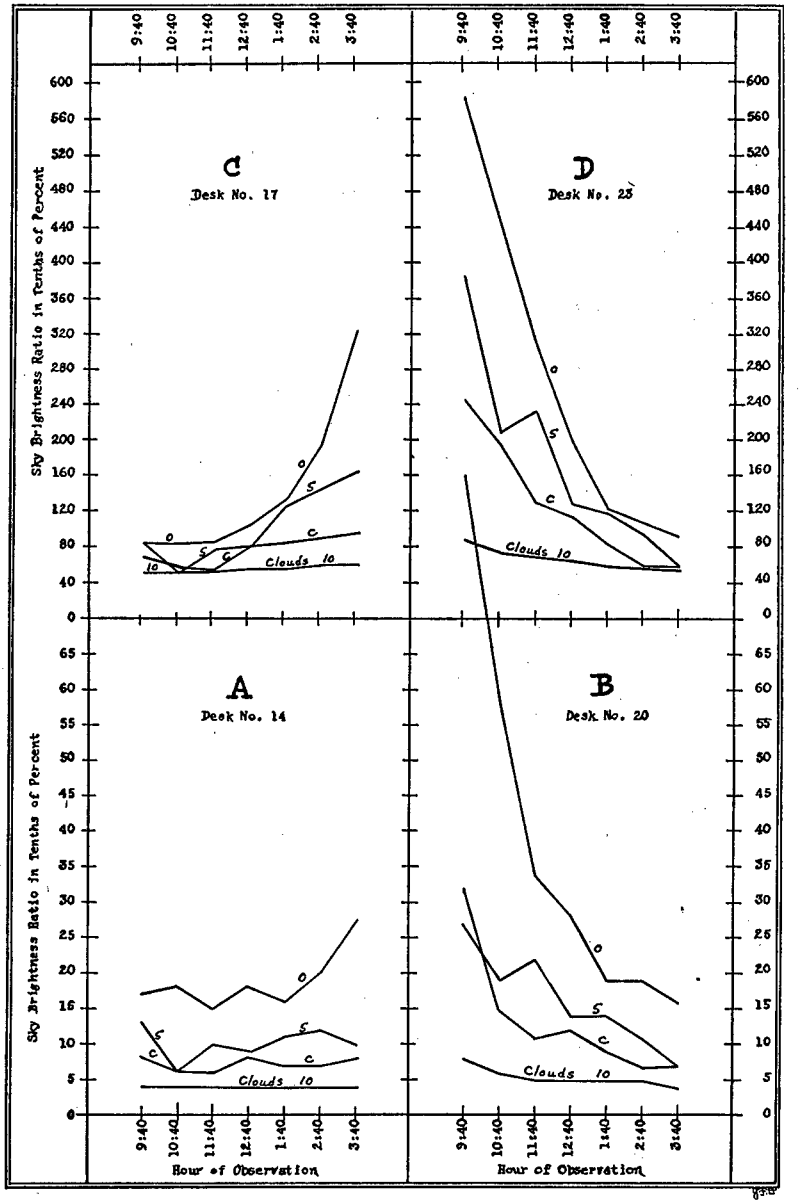


FIGURE 31.—Hourly values of the "sky brightness ratio" (means of nine monthly values) for four school desks for four specially chosen classes of clouds. Arranged by hour of observation, 9.40 a. m. to 3.40 p. m., Hagerstown, Md., September 17, 1923, to June 15, 1924

of four classes of clouds, 0, 5, 10, and C. Here, also, as in Figure 26 for the illumination ratio, there is to be noted the high values in the

forenoon for desks Nos. 20 and 23, and in the late afternoon for desks Nos. 14 and 17, especially for the cloud classes representing few clouds.

The monthly values are shown in Figure 32 for the same four desks and for four classes of clouds. In this figure the abscissae represent the months and a curve is given for each of the four cloud classes represented. In these figures the curves are of the same general types as are those for the illumination ratio, in that there is a mid-

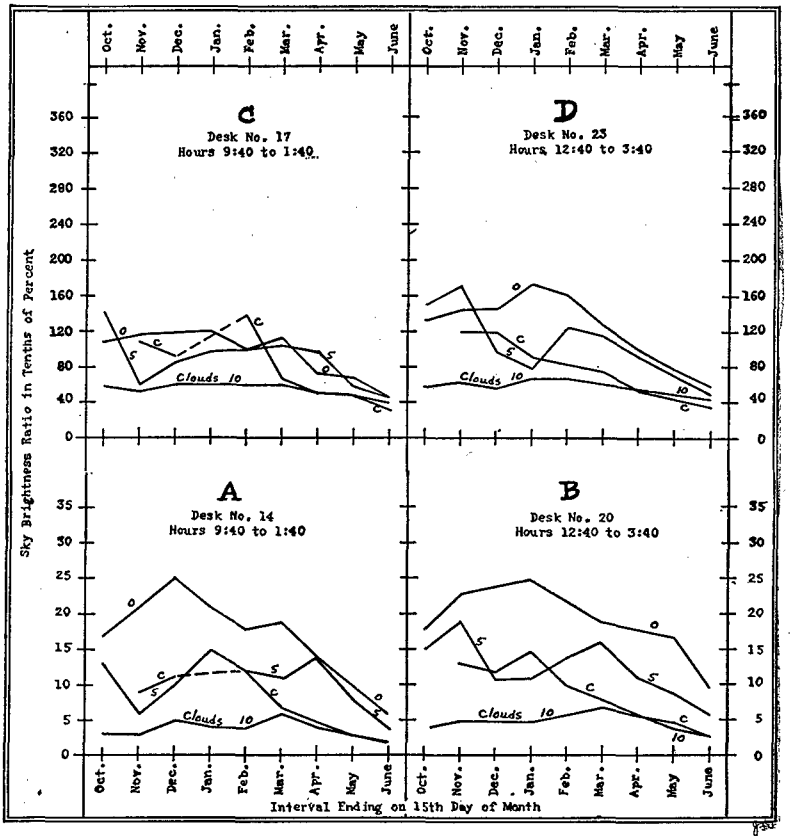


FIGURE 32.—Monthly values of the "sky brightness ratio" (means of values for only certain indicated hours) for four school desks for four specially chosen classes of clouds. Arranged by months, September 17, 1923, to June 15, 1924, Hagerstown, Md.

winter maximum. Perhaps, however, the fluctuations are not so pronounced.

There is a distinct difference between the variation with clouds of the sky brightness ratio from the corresponding variation of the illumination ratio. For the sky brightness ratio, in Figures 31 and 32 the lowest graph for each desk is for cloud class ten-tenths and the highest graphs is for class zero clouds, while for the illumination ratio in Figures 26 and 27 the reverse is true (except in Figure 26 for the hours of direct sunlight for each room). In other words, an increase

in the number of clouds produced an increase in the illumination ratio but a decrease in the sky brightness ratio. This also was shown by the bar graphs, Figures 25 and 30.

This effect is better shown perhaps by a comparison of Figures 33 and 34 with Figures 28 and 29. Figures 33 and 34 show for two desks, Nos. 14 and 20, the influence of clouds upon the sky brightness ratio. In these figures the clouds are represented as the abscissæ, and there is a line or curve for each month in the lower half of each figure, while in the upper half of each figure there is a line for each hour of observation. Thin clouds as well as thick clouds are represented. In these two figures (Nos. 33 and 34) there is a pronounced decrease in the sky brightness along the graphs from left to right corresponding to an increase in the extent of cloudiness. This is quite in contrast with Figures 28 and 29, in which there is an increase in the illumination ratio with an increase in clouds.

In Figures 33 and 34 the general downward trend is well marked for both the monthly graphs and also the hourly ones. In section A of Figure 33 the mean of the nine monthly values for zero clouds is 0.017 and the corresponding mean for class ten-tenths clouds is 0.004, the former being 425 per cent of the latter. These two values and the corresponding ones for the other classes of clouds as computed by averaging the monthly values are given for each desk in the second column of Table F. In like manner in section C of Figure 33 the mean of the seven hourly values for zero clouds is 0.019 and the corresponding mean value for ten-tenths clouds is 0.004, the former being 475 per cent of the latter. Considering these two values, it is seen that the sky brightness ratio is about 450 per cent higher for zero clouds than it is for ten-tenths clouds. This illustrates the change in the sky brightness ratio with an increase in the relative portion of the sky covered by clouds. The erratic high values shown in sections C and D of Figure 34 for desk No. 20 are due to the familiar action of direct sunlight on the windows, particularly at the times when few clouds were in the sky.

Relative to the monthly values of the sky brightness ratio as shown in Figure 32, lines for the two cloud classes zero and ten-tenths (these two are the highest and lowest in the figure) are relatively much closer together (especially desks 20 and 23 with a southeast exposure, sections B and D of the figure) in June than in the winter months such as in January. This shows that the sky brightness ratio is more nearly constant in summer than in winter.

As in the case of the illumination ratio the changes in the sky brightness ratio with clouds, hour of the day, and month of the year are not negligible. In Figure 32 the value of the ratio for any given month at a time of zero clouds is generally about four times that existing when there were ten-tenths clouds in the sky. Furthermore,

when changes in both cloud condition and season are taken into consideration, the relative change is much greater. For example, in section B of Figure 32, the maximum value of the sky brightness ratio for desk No. 20 for zero clouds in January is 8.3 times the minimum value for ten-tenths clouds in June. For desk No. 14 in section A of

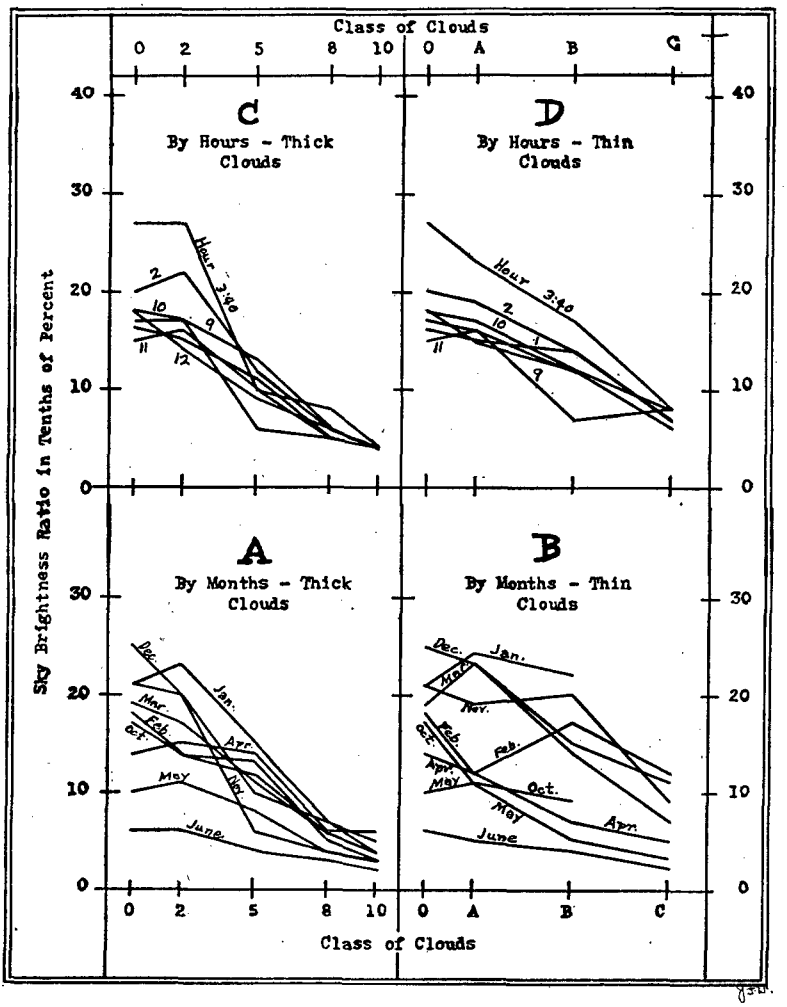


FIGURE 33.—Mean "sky brightness ratio" of desk No. 14 for each month and hour of observation. Arranged for thick and thin clouds, 9.40 a. m. to 3.40 p. m., September 17, 1923, to June 15, 1924, Hagerstown, Md.

Figure 32, the other desk back from the windows, the corresponding relative value is 12.5, while for the two desks near the windows (Nos. 17 and 23) the values are much smaller, being 3.0 and 3.9.[12]

[12] These four relative values are derived from only the values for cloud classes zero and ten-tenths. By taking the other classes also into consideration, slightly higher values would result at times.

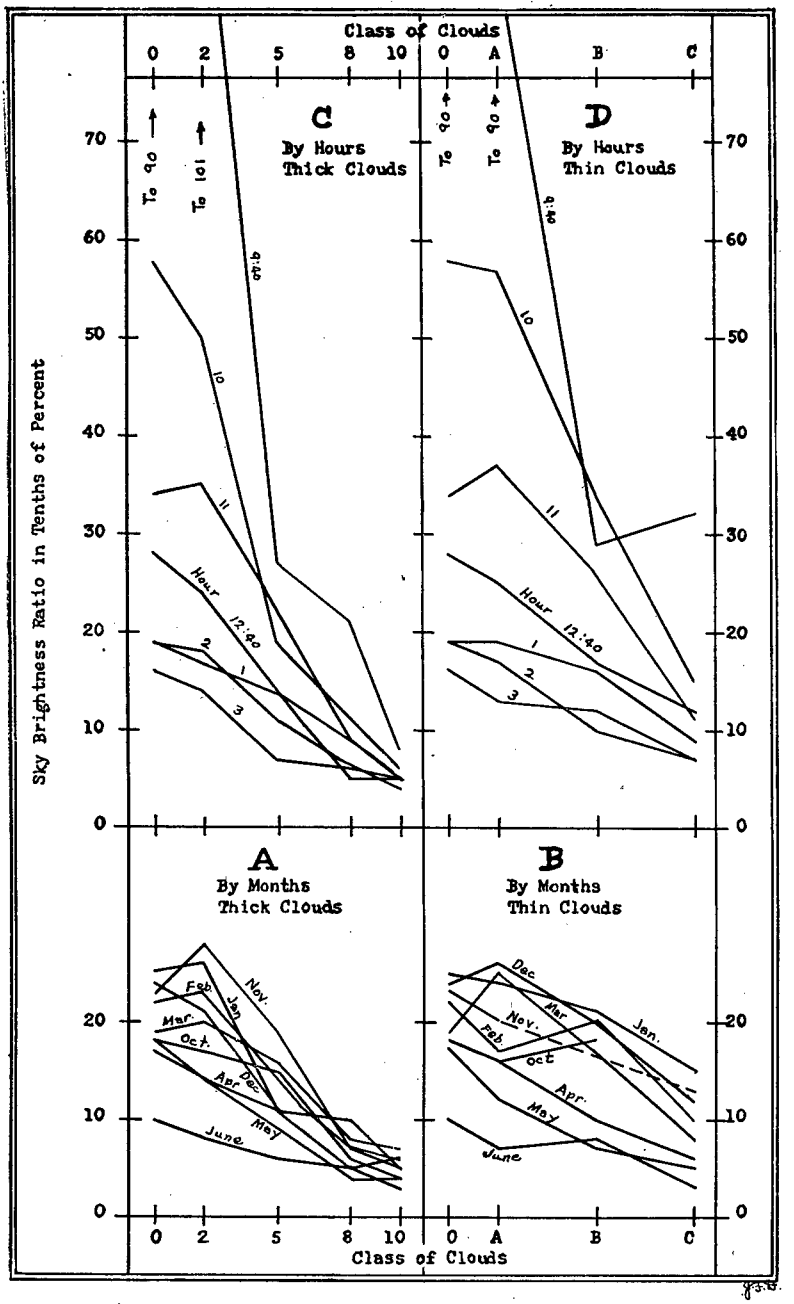


FIGURE 34.—Mean "sky brightness ratio" of desk No. 20 for each month and hour of observation. Arranged for thick and thin clouds, 9.40 a. m. to 3.40 p. m., September 17, 1923, to June 15, 1924, Hagerstown, Md.

TABLE 10.—*Ratio of the highest to the lowest tabular values for each desk for each the "illumination ratio" and the "sky brightness ratio," derived from the highest and the lowest values in Tables D and F for any month and for only the two cloud classes zero and ten-tenths*

Desk No.	Ratio of tabular values (maximum to minimum)		Desk No.	Ratio of tabular values (maximum to minimum)	
	Illumination ratio (from Table D)	Sky brightness ratio (from Table F)		Illumination ratio (from Table D)	Sky brightness ratio (from Table F)
Back from windows:			Near windows:		
4	8.1	10.0	1	12.6	3.8
5	7.2	12.0	2	12.1	4.3
6	8.4	11.0	3	10.9	4.7
7	6.5	8.3	10	12.0	3.3
8	7.0	9.3	11	10.4	3.0
9	8.2	11.0	12	10.6	3.1
13	5.4	11.5	16	11.0	3.8
14	6.3	12.5	17	9.8	3.0
15	7.7	19.0	18	9.2	3.2
19	7.2	6.7	22	9.5	5.5
20	7.0	8.3	23	11.2	3.8
21	6.2	11.0	24	11.9	3.2
Mean	7.1	10.9	Mean	10.9	3.7

A relative value of this kind is given for each desk in Table 10. The desks are classified into two groups, those near the windows and those back from the windows. Means for each group are given. The table shows that for the 12 desks back from the windows the mean value of these 12 special ratios is 7.1 for the "illumination ratio," while for the "sky brightness ratio" it is 10.9. On the other hand, for the 12 desks near the windows the mean for the "illumination ratio" is 10.9 and for the "sky brightness ratio" 3.7. This shows that for the desks back from the windows the sky brightness ratio is subject to slightly larger variations with changes in the percentage of overcast sky and seasonal variations than is the illumination ratio. On the other hand, for the desks near the windows, the sky brightness ratio is subject to much less variation than is the illumination ratio, the change in the former ratio being only 34 per cent of the change in the latter. It would seem, therefore, that the sky brightness ratio is on the whole more constant than is the illumination ratio. This is further shown by a comparison of Figures 27 and 32. In Figure 27, particularly section D for desk No. 23, the lines representing the different cloud classes are much farther apart (relatively as well as actually) than are the corresponding lines in Figure 32. It seems also that in Figure 32 the lines are more nearly horizontal than they are in Figure 27.

Since the sky brightness ratio probably is more nearly constant than is the illumination ratio, it appears that the sky brightness ratio would be more desirable than the illumination ratio for use in an illumination survey. Greater reliance could and should be placed upon the sky brightness ratio.

SUMMARY

In this division of the bulletin the variations of the illumination and brightness ratios have been considered. Each of these ratios

has been found to have at least three well-marked variations—with the season, with the direction of the exposure of the room, and with clouds.

These variations indicate that in making measurements to determine the general lighting of a room or to classify a number of rooms according to their illumination care should be exercised to note the attendant circumstances, such as the hour of the day, the season of the year, and nature and quantity of the clouds.

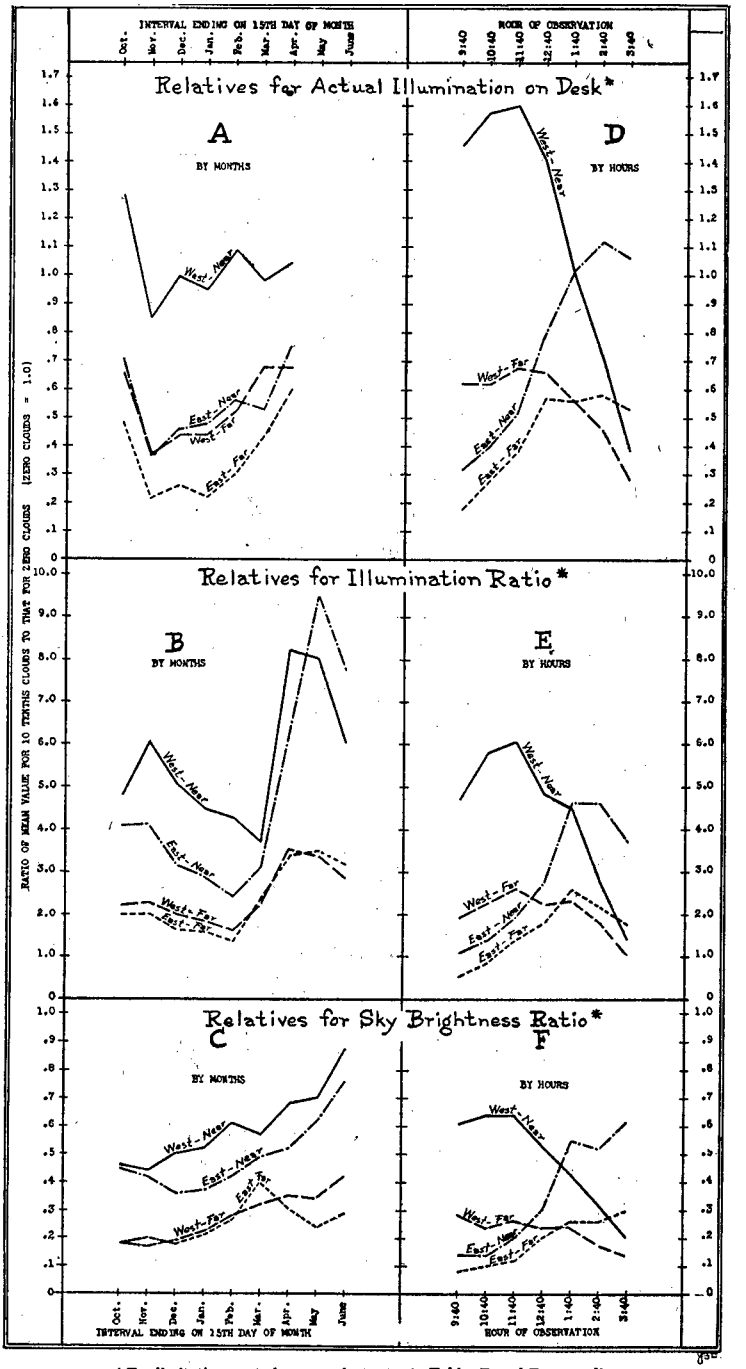
MISCELLANEOUS RELATIONSHIPS

In this division of the bulletin there will be considered a number of relationships between the illumination and the various physical factors; also the variations of these relationships with the seasons of the year, the time of the day, and the influence of clouds upon them. These relationships will usually be given in the form of ratios. Those considered include the distribution coefficient, the uniformity coefficient, and the relationships between the visible sky vault and the illumination measures. Also, a special subject and the first to be taken up is a summary of what has gone before. This is a comparison of the effect of ten-tenths thick clouds in contrast with zero clouds upon each of the three illumination measures, actual illumination on the desks, the illumination ratio, and the sky brightness ratio.

TOTALLY CLOUDY VERSUS CLOUDLESS SKY

In the tables and graphs which have preceded, when the values have been considered from the standpoint of clouds alone, the cloud classes corresponding to the highest and lowest values quite generally were those for zero clouds and ten-tenths clouds. The maximum at times corresponded to five-tenths or eight-tenths clouds, but when this occurred the value was usually not so very different from that for ten-tenths clouds. On the whole, the two classes selected to represent the extreme of cloudiness should be zero and ten-tenths clouds rather than any other two classes. The highest and the lowest values generally corresponded to zero and ten-tenths clouds, not only in the case of actual illumination on the desks but also for the other two kinds of measures, the illumination ratio and the sky brightness ratio. For the first and last of these measures, actual illumination and sky brightness ratio, the values for zero clouds are higher on the average than those for ten-tenths clouds, while for the illumination ratio the reverse is true. By obtaining a ratio of the values for these two cloud classes—i. e., for example, by dividing the illumination ratio for ten-tenths clouds by that for zero clouds—there is obtained a new ratio or relative which will provide a good picture of the extreme influence of clouds upon the illumination measurements.

Ratios of this type for each of the three kinds of measures are given in Tables 11 and 12 and in Figure 35. Table 11 gives the values for each month, October to June.



* For limitations as to hour, see footnotes to Tables D and F, appendix

FIGURE 35.—Relatives giving the ratio of the mean measure for six desks at ten-tenths clouds to the corresponding value of the measure at zero clouds. (Zero clouds=1.) Arranged for three kinds of measures (actual illumination on desks, illumination ratio, and sky brightness ratio) and giving values of relatives for groups of six desks both near and far from the windows, and with the two directions of window exposure

TABLE 11.—*Monthly relative values between two classes of clouds for each row of school desks for each of the three kinds of measures, actual illumination on desks illumination ratio, and sky brightness ratio, arranged by months, giving the ratio of the value of the measure for ten-tenths clouds to that for zero clouds, covering the interval September 17, 1923, to June 15, 1924, at Hagerstown, Md.*

Room exposure	Proximity to windows	Floor of building	Desks Nos.—	Interval ending on the 15th day of the indicated month									
				All months	October	November	December	January	February	March	April	May	June
RATIO OF THE MEAN VALUE OF THE ACTUAL ILLUMINATION ON DESKS [1] FOR TEN-TENTHS CLOUDS TO THAT FOR THE SAME THREE DESKS FOR ZERO CLOUDS. (ZERO CLOUDS=1)													
East	Near	First	1, 2, 3	0.54	0.68	0.34	0.44	0.49	0.60	0.53	0.69	-----	-----
West	do	do	10, 11, 12	1.06	1.25	.87	1.02	.99	1.13	1.02	1.08	-----	-----
Do	do	Second	16, 17, 18	1.01	1.33	.83	.97	.91	1.05	.93	.99	-----	-----
East	do	do	22, 23, 24	.56	.74	.38	.48	.46	.52	.53	.82	-----	-----
Do	Far	First	4, 5, 6	.33	.41	.20	.25	.21	.32	43	.59	-----	-----
West	do	do	7, 8, 9	.59	.67	.39	.48	.48	.56	.71	.77	-----	-----
Do	do	Second	13, 14, 15	.46	.66	.35	.39	.40	.47	.65	.60	-----	-----
East	do	do	19, 20, 21	.35	.57	.23	.27	.23	.29	.43	.60	-----	-----
Means:													
East	Near	Both	1, 2, 3, 22, 23, 24	.55	.71	.36	.46	.48	.56	.53	.76	-----	-----
West	do	do	10, 11, 12, 16, 17, 18	1.04	1.29	.85	1.00	.95	1.09	.98	1.04	-----	-----
East	Far	do	4, 5, 6, 19, 20, 21	.34	.49	.22	.26	.22	.30	.43	.60	-----	-----
West	do	do	7, 8, 9, 13, 14, 15	.52	.66	.37	.44	.44	.52	.68	.68	-----	-----
RATIO OF THE MEAN VALUE OF THE ILLUMINATION RATIO [2] FOR TEN-TENTHS CLOUDS TO THAT FOR THE SAME THREE DESKS FOR ZERO CLOUDS. (ZERO CLOUDS=1)													
East	Near	First	1, 2, 3	3.84	4.32	3.97	3.04	2.88	2.55	3.16	5.86	9.15	7.45
West	do	do	10, 11, 12	5.23	4.64	6.15	5.08	4.66	4.42	3.87	7.99	7.99	6.17
Do	do	Second	16, 17, 18	5.11	4.96	6.03	5.06	4.33	4.12	3.53	8.24	8.05	5.79
East	do	do	22, 23, 24	3.92	3.88	4.31	3.29	2.88	2.34	3.07	6.79	9.80	8.07
Do	Far	First	4, 5, 6	2.04	1.67	1.95	1.61	1.64	1.40	2.55	3.39	3.07	2.50
West	do	do	7, 8, 9	2.40	2.25	2.47	2.11	2.00	1.80	2.32	3.89	3.39	3.08
Do	do	Second	13, 14, 15	2.16	2.18	2.13	1.87	1.71	1.46	2.14	3.14	3.33	2.60
East	do	do	19, 20, 21	2.16	2.31	2.09	1.68	1.53	1.33	2.28	3.42	3.93	3.82
Means:													
East	Near	Both	1, 2, 3, 22, 23, 24	3.88	4.10	4.14	3.16	2.88	2.44	3.12	6.32	9.48	7.76
West	do	do	10, 11, 12, 16, 17, 18	5.17	4.80	6.09	5.07	4.50	4.27	3.70	8.12	8.02	5.98
East	Far	do	4, 5, 6, 19, 20, 21	2.10	1.99	2.02	1.64	1.58	1.36	2.42	3.40	3.50	3.16
West	do	do	7, 8, 9, 13, 14, 15	2.28	2.22	2.30	2.00	1.86	1.63	2.23	3.52	3.36	2.84
RATIO OF THE MEAN VALUE OF THE SKY BRIGHTNESS RATIO [2] FOR TEN-TENTHS CLOUDS TO THAT FOR THE SAME THREE DESKS FOR ZERO CLOUDS. (ZERO CLOUDS=1)													
East	Near	First	1, 2, 3	0.45	0.43	0.40	0.34	0.36	0.42	0.51	0.48	0.60	0.79
West	do	do	10, 11, 12	.57	.45	.44	.51	.54	.62	.60	.67	.70	.90
Do	do	Second	16, 17, 18	.56	.47	.43	.50	.51	.60	.54	.70	.69	.85
East	do	do	22, 23, 24	.46	.43	.43	.39	.38	.41	.47	.57	.65	.74
Do	Far	First	4, 5, 6	.24	.12	.20	.18	.24	.26	.44	.31	.21	.25
West	do	do	7, 8, 9	.28	.15	.17	.20	.22	.30	.36	.37	.31	.43
Do	do	Second	13, 14, 15	.27	.21	.17	.18	.21	.25	.29	.33	.38	.40
East	do	do	19, 20, 21	.22	.25	.20	.18	.18	.25	.35	.31	.27	.33
Means:													
East	Near	Both	1, 2, 3, 22, 23, 24	.46	.43	.42	.36	.37	.42	.49	.52	.62	.76
West	do	do	10, 11, 12, 16, 17, 18	.56	.46	.44	.50	.52	.61	.57	.68	.70	.88
East	Far	do	4, 5, 6, 19, 20, 21	.23	.18	.20	.18	.21	.26	.40	.31	.24	.29
West	do	do	7, 8, 9, 13, 14, 15	.28	.18	.17	.19	.22	.28	.32	.35	.34	.42

[1] Monthly values of actual illumination on desks are based upon the means of values for 7 hours.

[2] Monthly values of illumination ratio and sky brightness ratio are based upon the means of values for only 4 or 5 hours; for rooms with a western exposure the hours are 9.40 a. m. to 1.40 p. m., while for rooms with an eastern exposure the hours are 12.40 p. m. to 3.40 p. m.

TABLE 12.—*Hourly relative values between two classes of clouds for each row of school desks for each of the three kinds of measures, actual illumination on desks, illumination ratio, and sky brightness ratio, arranged by hour of observation, and giving the ratio of the value of the measure for ten-tenths clouds to that for zero clouds, covering the interval September 17, 1923, to June 15, 1924, at Hagerstown, Md.*

Room exposure	Proximity to windows	Floor of building	Desks Nos.—	All hours	Hour of observation						
					9.40	10.40	11.40	12.40	1.40	2.40	3.40
RATIO OF THE MEAN VALUE OF THE ACTUAL ILLUMINATION ON DESKS [1] FOR TEN-TENTHS CLOUDS TO THAT FOR THE SAME THREE DESKS FOR ZERO CLOUDS. (ZERO CLOUDS=1)											
East	Near	First	1, 2, 3	0.54	0.32	0.38	0.48	0.74	1.03	1.17	1.15
West	do	do	10, 11, 12	1.06	1.49	1.68	1.65	1.43	1.01	.72	.40
Do	do	Second	16, 17, 18	1.01	1.42	1.47	1.56	1.37	1.02	.72	.35
East	do	do	22, 23, 24	.56	.32	.43	.56	.85	1.01	1.06	.98
Do	Far	First	4, 5, 6	.34	.17	.27	.37	.57	.52	.61	.57
West	do	do	7, 8, 9	.60	.70	.70	.76	.70	.57	.49	.31
Do	do	Second	13, 14, 15	.51	.53	.53	.60	.63	.55	.43	.26
East	do	do	19, 20, 21	.36	.19	.28	.40	.57	.60	.56	.49
Means:											
East	Near	Both	1, 2, 3, 22, 23, 24	.55	.32	.40	.52	.80	1.02	1.12	1.06
West	do	do	10, 11, 12, 16, 17, 18	1.04	1.46	1.58	1.60	1.40	1.02	.72	.38
East	Far	do	4, 5, 6, 19, 20, 21	.35	.18	.28	.38	.57	.56	.58	.53
West	do	do	7, 8, 9, 13, 14, 15	.56	.62	.62	.68	.66	.56	.46	.28
RATIO OF THE MEAN VALUE OF THE ILLUMINATION RATIO [2] FOR TEN-TENTHS CLOUDS TO THAT FOR THE SAME THREE DESKS FOR ZERO CLOUDS. (ZERO CLOUDS=1)											
East	Near	First	1, 2, 3	2.07	1.13	1.36	1.77	2.56	4.45	4.77	3.83
West	do	do	10, 11, 12	3.38	4.81	6.06	5.27	4.97	4.50	2.80	1.45
Do	do	Second	16, 17, 18	3.25	4.65	5.58	6.87	4.73	4.55	2.84	1.34
East	do	do	22, 23, 24	2.06	1.01	1.42	2.11	2.89	4.78	4.48	3.53
Do	Far	First	4, 5, 6	1.04	.45	.81	1.26	1.76	2.41	2.09	1.73
West	do	do	7, 8, 9	1.93	2.16	2.57	2.82	2.26	2.25	1.91	1.08
Do	do	Second	13, 14, 15	1.75	1.67	2.00	2.41	2.21	2.39	1.69	.94
East	do	do	19, 20, 21	1.24	.58	.93	1.51	1.90	2.76	2.21	1.72
Means:											
East	Near	Both	1, 2, 3, 22, 23, 24	2.06	1.07	1.39	1.94	2.78	4.62	4.62	3.68
West	do	do	10, 11, 12, 16, 17, 18	3.32	4.73	5.82	6.07	4.85	4.52	2.82	1.40
East	Far	do	4, 5, 6, 19, 20, 21	1.14	.52	.87	1.38	1.83	2.58	2.15	1.72
West	do	do	7, 8, 9, 13, 14, 15	1.84	1.92	2.28	2.62	2.24	2.32	1.80	1.01
RATIO OF THE MEAN VALUE OF THE SKY BRIGHTNESS RATIO [2] FOR TEN-TENTHS CLOUDS TO THAT FOR THE SAME THREE DESKS FOR ZERO CLOUDS. (ZERO CLOUDS=1)											
East	Near	First	1, 2, 3	0.23	0.14	0.14	0.18	0.27	0.49	0.53	0.64
West	do	do	10, 11, 12	.40	.63	.66	.64	.53	.43	.34	.20
Do	do	Second	16, 17, 18	.39	.59	.61	.63	.53	.43	.31	.19
East	do	do	22, 23, 24	.24	.14	.15	.22	.32	.61	.51	.59
Do	Far	First	4, 5, 6	.14	.06	.10	.12	.20	.24	.27	.31
West	do	do	7, 8, 9	.23	.28	.28	.28	.24	.24	.19	.15
Do	do	Second	13, 14, 15	.24	.27	.19	.23	.25	.29	.16	.12
East	do	do	19, 20, 21	.15	.09	.10	.13	.20	.29	.24	.28
Means:											
East	Near	Both	1, 2, 3, 22, 23, 24	.24	.14	.14	.20	.30	.55	.52	.62
West	do	do	10, 11, 12, 16, 17, 18	.40	.61	.64	.64	.53	.43	.32	.20
East	Far	do	4, 5, 6, 19, 20, 21	.14	.08	.10	.12	.20	.26	.26	.30
West	do	do	7, 8, 9, 13, 14, 15	.24	.28	.24	.26	.24	.26	.18	.14

[1] Means of the 7 monthly intervals, October to April.
[2] Means of the 9 monthly intervals, October to June.

The table is divided into three similar sections, one for each of the three kinds of measures, actual illumination on desks, illumination ratio, and sky brightness ratio. There is first shown in each section of the table a mean value for each group of 3 desks in a row, there being two rows in each of the 4 rooms in which observations were made. At the bottom of each section of the table are four lines of values, each line being a mean for a pair of corresponding rows of desks for each exposure, both near and far from the windows. There is a set of mean values for the two rows of desks near the windows with an eastern exposure, and a similar set of values for the rows of desks far from the windows with an eastern exposure; also, other values for the desks near and far from the windows with a western exposure. It is these mean values of the table which are shown graphically in sections A, B, and C, the left-hand half, of Figure 35. Hourly values of this special ratio are given in Table 12 and shown graphically in sections D, E, and F, the right-hand half, of Figure 35. Each graph of the figure is marked as to whether the exposure is eastern or western and whether the desks were near or far from the windows.

An inspection of Figure 35 shows that all the values for the sky brightness ratio are less than unity, a few of the values for the actual illumination are above unity, and most of the values for the illumination ratio are above unity. This signifies that between the times October to June, or from 9.40 a. m. to 3.40 p. m., the sky brightness ratio for ten-tenths clouds is never as large on the average as it is for zero clouds; for the illumination ratio, it signifies that the ratio is larger, and generally many times larger, for ten-tenths clouds than it is for zero clouds; and for the actual illumination, it signifies that under certain conditions as to direction of exposure and location within the room the illumination is actually higher with ten-tenths clouds than it is with zero clouds.

A study of the curves in Figure 35 brings out the fact that there are a number of more or less definite changes of this special ratio. In other words, the influence of ten-tenths clouds as compared with zero clouds upon the illumination and the indoor-outdoor ratios is not constant, but varies according to certain principles. Although the laws of change of this ratio are rather definite, it is not easy to comprehend their full significance, or rather the changes in the illumination when all of the laws are operating. These laws or principles will now be taken up.

SEASONAL CHANGE

When the monthly tabulations shown in the left-hand half of Figure 35 are considered, in each of the three sections (with the possible exception of section C for the sky brightness ratio) the curves have a fairly good minimum in midwinter. This is especially well

marked in the cases of the actual illumination and the illumination ratio. Also, in each of the three sections, the various curves are quite closely parallel, thereby showing that the seasons have the same effect upon all of the curves independent of exposure and distance from the windows.

DIURNAL CHANGES

For the hourly values in the right-hand half of the figure, each of the curves shows a fairly definite maximum in the proximity of noon. For the desks with a western exposure, the maximum occurs at 11.40 a. m., while for an eastern exposure it usually occurs at 1.40 or 2.40 p. m. In other words the time of the maximum for the western exposure was about two hours after the beginning of the daily observations, and for the eastern exposure it was one or two hours before the end of the day. It may be that this interpretation of the time of maximum is not best, but that the direct sunlight is the prime causal influence. The best explanation may be that the maximum for the western exposure occurred about one hour or a trifle more before direct sunlight would reach that side of the building (the building is oriented 31° west of south), and that for the eastern exposure the maximum occurred about an hour or more after direct sunshine had ceased to fall on that side of the building.

Taken on the whole throughout the day, the ratios for the desks with a western exposure decline as the day advances, while for the eastern exposure the trend of the ratios is to rise as the day advances. This tendency is quite marked; in fact, it is so marked as to nearly blot out the midday maximum. The combination of conditions giving the greater slope to the curve is the same for the two exposures. It is the proximity to the windows. The curves for the desks near the windows (labeled "west-near" or "east-near") always rise or fall more rapidly than the curves for the desks far from the windows (labeled "west-far" and "east-far"), respectively.

With further reference to the daily maximum, the desks with a western exposure have a higher maximum than the desks with an eastern exposure. For the desks near the windows, this is the case for each of the type of measures, i. e., the maximum for the "west-near" curve is always higher than the maximum for the "east-near" curve. This is also generally true for the desk back from the windows, the maximum for the "west-far" curves generally being higher than or as high as the "east-far" curves. In each section the curve having the highest maximum is that for "west-near."

BEST TYPE OF CURVES

A query which it is probably advisable to discuss at this point is whether good illumination corresponds to high curves on this figure or to low curves. Perhaps in this connection it would be well to

focus all attention upon ratios based on the actual illumination, i. e., sections A and D of the figure. Since the shortcomings of natural illumination usually are the deficiency of illumination generally accompanying ten-tenths or total cloudiness, it would seem desirable that the illumination under these conditions of cloudiness be as high or as nearly the same as that for zero cloudiness. This would mean that for this special ratio under consideration, the best value is one nearest to unity. For the actual illumination, since most of the curves are less than unity, the higher curves probably correspond to the better lighting. For these special ratios prepared for the illumination ratio and the sky brightness ratio, other factors need to be taken into consideration, but it is probable that here also, and especially for the sky brightness ratio for which the curves in Figure 35 are quite low, the higher the curve the better is the lighting.

DISTANCE TO THE WINDOWS

The values of this special ratio for the rows of desks near the windows are always higher than the values for the desks far from the windows. This is also true for each of the three kinds of measures, actual illumination on desks, the illumination ratio, and the sky brightness ratio. In every case, and for both the monthly tabulations and the hourly tabulations, the curves for the desks having a western exposure and near the windows (marked "west-near") are higher than those with a western exposure and far from the windows (marked "west-far"); also, the curves marked "east-near" are above those marked "east-far." This signifies that the clouds cause less relative change in the illumination near the windows than they do far from the windows.

EXPOSURE DIRECTION

Another principle, a very important one, and one which is a controlling factor in the changes of this special ratio, is the direction of exposure of the room in which the desks are situated. In the monthly tabulations graphed in the left-hand half of Figure 35, the higher curves always correspond to the northwestern exposure. The curves marked "west-near" are always above those marked "east-near," and those labeled "west-far" are always higher than those labeled "east-far." The difference is always quite pronounced in the case of the monthly tabulations. This difference is also evident in the hourly tabulations, but it is not so pronounced. Here it is quite largely masked by the slope of the curves. It is evidenced, however, by the difference in the height of the maxima for the two exposures as previously mentioned. In the monthly tabulations the higher, and presumably the better, curves are for the desks having a northwestern exposure, and in the hourly tabulations each room has its

maximum and presumably best conditions at an hour when the windows are protected from direct rays of the sun. From this it is to be seen that clouds produce less percentage change in a room having a protected exposure than in a room having windows exposed to direct sunlight.

RELATIVE ILLUMINATION WITH A CLOUDY SKY

In addition to showing the laws of change of this special ratio and the physical conditions corresponding to the least influence of clouds upon the illumination, the curves of figure 35 show approximately how much actual illumination in foot-candles can be obtained on the average with ten-tenths clouds as compared to that obtained with zero clouds. The average for all 24 desks for the 7 months, October to April, is 0.61, showing that the illumination with ten-tenths clouds is on the average 61 per cent of that obtained with zero clouds. This value is perhaps unduly high because of the high values for the 6 desks near the windows having a northwestern exposure (see line 10, Table 11). Perhaps a reasonably approximate rule is that the illumination with ten-tenths clouds on the average is about half that for zero clouds which value is also confirmed by data of another kind to be presented in a later section. Under many physical conditions, however, it is as low as about one-fifth that for zero clouds, and under other conditions it occasionally is as high as one and one-half times that for zero clouds.

DISTRIBUTION COEFFICIENT

The distribution coefficient was used in Public Health Bulletin No. 159 as the ratio of the illumination on a desk near the windows to that on the corresponding desk in the row farthest from the windows. In that bulletin there were given the hourly and monthly mean values of this coefficient, but without reference to the condition of cloudiness existing at the time of making the measures; i. e., all cloud conditions were averaged together. Three values were given for each room, one value for each pair of desks upon which the illumination was measured. In Tables 13 and 14 of this bulletin, however, there are given the values of the coefficient classified according to the clouds; but in computing the coefficient, the values of the illumination for the three desks in each row were averaged together, thereby giving only one mean value of the coefficient for each room as applying under each of the various conditions of cloudiness and time of day or season of the year.

TABLE 13.—*Hourly values of the distribution coefficient—Ratio of the mean illumination on the 3 desks in the row nearest the windows to the mean for the corresponding 3 desks in the row farthest from the windows*

Cloud class	All hours	Distribution coefficient at the indicated hours						
		9.40	10.40	11.40	12.40	1.40	2.40	3.40
ROOM NO. 107—SOUTHEAST EXPOSURE—DESKS NOS. 1-6								
0	8.9	6.5	10.7	11.8	10.5	7.5	7.6	7.8
2	9.7	5.7	12.5	12.7	11.3	9.4	8.7	7.9
5	12.6	12.0	14.5	14.9	11.6	11.4	11.3	12.7
8	14.7	13.7	18.6	16.5	14.9	12.8	15.2	11.2
10	14.5	12.4	14.8	15.2	13.7	15.0	14.7	15.7
A	9.7	6.5	10.7	12.6	11.2	10.7	8.1	7.9
B	11.5	11.4	12.4	15.1	11.7	10.2	10.1	9.4
C	11.9	8.0	14.5	14.6	11.0	12.1	11.6	11.2
ROOM NO. 104—NORTHWEST EXPOSURE—DESKS NOS. 7-12								
0	5.5	4.6	4.1	4.5	4.7	5.8	6.8	8.1
2	5.8	4.4	4.6	4.6	5.5	6.0	7.2	8.4
5	7.2	6.1	5.7	6.2	5.9	7.8	8.4	10.5
8	9.2	9.2	8.5	8.8	8.3	9.8	10.3	9.2
10	10.0	9.7	9.9	9.9	9.7	10.3	10.1	10.5
A	5.8	4.9	4.8	4.7	5.3	6.4	6.8	7.6
B	7.0	6.7	5.5	6.0	6.8	7.0	8.4	8.4
C	8.5	7.0	7.8	8.4	6.9	8.6	10.0	10.7
ROOM NO. 204—NORTHWEST EXPOSURE—DESKS NOS. 13-18								
0	6.0	4.2	4.1	4.7	5.2	6.8	7.7	9.3
2	6.5	4.3	4.6	5.1	6.1	7.6	8.5	9.3
5	8.4	6.6	7.0	7.2	7.1	8.6	10.4	11.9
8	10.8	10.9	9.2	10.2	9.1	11.5	12.7	11.9
10	12.0	11.4	11.2	12.2	11.3	12.7	12.7	12.6
A	6.5	5.4	4.8	5.0	5.7	7.0	7.7	9.7
B	7.5	6.5	6.1	7.0	6.7	8.5	8.7	9.3
C	9.6	8.1	8.6	8.9	7.4	10.8	12.7	11.0
ROOM NO. 207—SOUTHEAST EXPOSURE—DESKS NOS. 19-24								
0	6.7	6.7	7.4	8.2	7.0	6.3	5.6	5.5
2	7.5	5.8	10.2	8.8	8.1	8.1	5.9	5.6
5	9.4	13.7	9.5	10.3	8.3	8.0	7.9	7.9
8	10.6	10.4	11.0	11.2	10.4	11.0	10.7	9.5
10	10.8	11.0	11.2	11.4	10.3	10.5	10.4	11.0
A	7.0	6.7	8.0	8.4	7.1	6.8	6.0	6.0
B	8.7	9.3	10.8	9.2	7.8	10.4	6.8	6.7
C	9.4	10.3	10.6	11.0	8.4	9.3	8.0	8.4
MEAN FOR ROOMS NOS. 107 AND 207—SOUTHEAST EXPOSURE								
0	7.8	6.6	9.0	10.0	8.8	6.9	6.6	6.6
2	8.7	5.8	11.4	10.8	9.7	8.8	7.3	6.8
5	11.0	12.8	12.0	12.6	10.0	9.7	9.6	10.3
8	12.6	12.0	14.8	13.8	12.6	11.9	13.0	10.4
10	12.7	11.7	13.0	13.3	12.0	12.8	12.6	13.4
A	8.4	6.6	9.4	10.5	9.2	8.8	7.0	7.0
B	10.1	10.4	11.6	12.2	9.8	10.3	8.4	8.0
C	10.7	9.2	12.6	12.8	9.7	10.7	9.8	9.8
MEAN FOR ROOMS NOS. 104 AND 204—NORTHWEST EXPOSURE								
0	5.8	4.4	4.1	4.6	5.0	6.3	7.2	8.7
2	6.1	4.4	4.6	4.8	5.8	6.8	7.8	8.8
5	7.8	6.4	6.4	6.7	6.5	8.2	9.4	11.2
8	10.0	10.0	8.8	9.5	8.7	10.6	11.5	10.6
10	11.0	10.6	10.6	11.0	10.5	11.5	11.4	11.6
A	6.1	5.2	4.8	4.8	5.5	6.7	7.2	8.6
B	7.3	6.6	5.8	6.5	6.8	7.8	8.6	8.8
C	9.1	7.6	8.2	8.6	7.2	9.7	11.4	10.8

TABLE 14.—*Monthly values of the distribution coefficient—Ratio of the mean illumination on the 3 desks in the row nearest the windows to the mean for the corresponding 3 desks in the row farthest from the windows*

Cloud class	All months	Distribution coefficient for the indicated monthly intervals						
		Oct.[1]	Nov.[1]	Dec.[1]	Jan.[1]	Feb.[1]	Mar.[1]	Apr.[1]
ROOM NO. 107—SOUTHEAST EXPOSURE—DESKS NOS. 1-6								
0	9.3	13.3	9.4	7.0	6.4	7.9	9.6	11.4
2	9.9	15.1	10.8	9.0	6.4	7.7	9.5	10.7
5	13.1	18.1	12.8	11.2	10.8	12.5	12.9	13.7
8	15.4	24.1	15.6	13.8	13.6	13.4	13.7	13.8
10	14.7	21.9	15.8	12.3	14.5	14.6	11.8	11.7
A	9.8	14.3	9.5	7.4	5.6	8.5	9.1	14.1
B	11.7	15.8	10.1	11.4	9.9	11.5	10.8	12.6
C	13.2	--------	13.8	8.6	15.1	13.5	12.3	16.1
ROOM NO. 104—NORTHWEST EXPOSURE—DESKS NOS. 7-12								
0	5.6	6.2	5.5	4.9	5.4	5.2	5.7	6.2
2	6.0	7.5	5.7	5.4	5.3	6.1	6.1	5.9
5	7.1	9.2	7.3	7.3	6.2	6.5	6.1	6.9
8	9.5	10.6	10.3	9.7	9.1	8.8	7.4	10.5
10	10.4	11.6	12.0	10.4	11.1	10.5	8.2	8.8
A	5.9	7.0	5.6	5.0	5.4	7.2	5.2	5.9
B	6.8	6.9	6.1	7.1	6.9	5.9	6.4	8.1
C	8.7	--------	9.7	7.5	7.3	10.1	7.9	9.8
ROOM NO. 204—NORTHWEST EXPOSURE—DESKS NOS. 13-18								
0	6.2	7.5	5.9	4.8	5.5	5.9	6.9	6.6
2	6.5	9.1	6.0	5.4	5.3	6.0	6.7	6.9
5	7.8	11.3	8.6	7.7	6.1	5.9	7.2	7.7
8	10.5	13.1	12.2	9.9	9.0	7.8	9.0	12.2
10	11.9	15.1	13.9	11.8	12.4	9.5	9.8	10.9
A	6.1	8.7	6.3	5.0	5.5	4.6	5.9	6.5
B	7.2	8.5	6.0	7.1	7.2	5.3	7.9	8.6
C	9.0	--------	9.8	8.4	8.0	8.4	9.3	10.2
ROOM NO. 207—SOUTHEAST EXPOSURE—DESKS NOS. 19-24								
0	7.1	9.1	7.3	5.9	5.6	6.5	7.8	7.5
2	7.5	9.6	8.1	7.4	5.5	6.2	8.6	7.4
5	9.8	10.7	10.1	8.9	8.7	11.0	9.1	10.1
8	10.6	11.8	11.1	9.7	9.6	10.5	10.5	11.1
10	11.0	11.8	12.2	10.4	11.4	11.6	9.6	10.3
A	7.4	10.0	7.5	6.0	5.2	7.4	7.1	8.4
B	8.2	9.7	9.1	7.4	3.0	9.0	9.4	9.7
C	9.9	--------	11.2	7.9	11.0	8.7	10.9	9.6
MEAN FOR ROOMS NOS. 107 AND 207—SOUTHEAST EXPOSURE								
0	8.2	11.2	8.4	6.4	6.0	7.2	8.7	9.4
2	8.7	12.4	9.4	8.2	6.0	7.0	9.0	9.0
5	11.5	14.4	11.4	10.0	9.8	11.8	11.0	11.9
8	13.0	18.0	13.4	11.8	11.6	12.0	12.1	12.4
10	12.9	16.8	14.0	11.4	13.0	13.1	10.7	11.0
A	8.6	12.2	8.5	6.7	5.4	8.0	8.1	11.2
B	10.0	12.8	9.6	9.4	6.4	10.2	10.1	11.2
C	11.5	--------	12.5	8.2	13.0	11.1	11.6	12.8
MEAN FOR ROOMS NOS. 104 AND 204—NORTHWEST EXPOSURE								
0	5.9	6.8	5.7	4.8	5.4	5.6	6.3	6.4
2	6.2	8.3	5.8	5.4	5.3	6.0	6.4	6.4
5	7.4	10.2	8.0	7.5	6.2	6.2	6.6	7.3
8	10.0	11.8	11.2	9.8	9.0	8.3	8.2	11.4
10	11.2	13.4	13.0	11.1	11.8	10.0	9.0	9.8
A	6.0	7.8	6.0	5.0	5.4	5.9	5 6	6 2
B	7.0	7.7	6.0	7.1	7.0	5.6	7.2	8.4
C	8.9	--------	9.8	8.0	7.6	9.2	8.6	10.0

[1] Interval ending on the 15th day of the indicated month.

DIURNAL VARIATIONS

The hourly averages are given in Table 13. At the bottom of the table are given a set of means for rooms 107 and 207 with a southeast exposure and another set of means for rooms 104 and 204 with a northwest exposure. The behavior in these two cases is far from identical. In the case of rooms 107 and 207, for zero clouds and a few thin clouds such as class A, the mean distribution coefficient has a maximum near noon and the value at 9.40 a. m. is no higher than the value at 3.40 p. m., but in the case of rooms 104 and 204 the forenoon values are about constant and the maximum occurs late in the afternoon. The value of the coefficient in the late afternoon is about twice that prevailing during the forenoon. For ten-tenths clouds on the other hand, the two cases with the two directions of exposure act much the same, i. e., there is little change during the day and the maximum, if any be present, occurs late in the afternoon for both exposures.

SEASONAL VARIATION

The monthly averages of the distribution coefficient are given in Table 14. In the case of rooms 107 and 207 with a southeast exposure, for zero clouds and few thin clouds such as class A, there is a pronounced midwinter minimum; in the case of rooms 104 and 204 with a northwest exposure, however, there is a midwinter minimum but not nearly so well marked as exists for rooms 107 and 207. For ten-tenths clouds, on the other hand, there is not much change with the season. If any seasonal change in the coefficient does exist for ten-tenths clouds, it probably is a slight decline in the coefficient from October to April, the limits of the period covered by the values.

VARIATIONS CAUSED BY CLOUDS

The influence of clouds upon the distribution coefficient is quite marked and the extent of the variations caused by the clouds is different at different times of the day and the seasons of the year. Whenever the coefficient is at a minimum, the value corresponding to ten-tenths clouds is about twice that for zero clouds. This is true for a minimum occurring either at some particular hour of the day such as 9.40 a. m. for rooms 104 and 204, or 3.40 p. m. for rooms 107 and 207, or at some particular season of the year such as in January for both groups of rooms 104 and 204 and rooms 107 and 207. At other times there is always an important change in the coefficient as the number of clouds increases, but the value of the coefficient at ten-tenths clouds in less than twice that for zero clouds. The cloud class for which the change in the coefficient is least is ten-tenths thick clouds. In fact, under these particular cloud conditions, the coefficient is fairly constant, even for all hours of the day, months of the year, or direction of exposure. Such variations in the coeffi-

cient as are shown under these cloud conditions are relatively small and comparatively free from any systematic law of change.

UNIFORMITY COEFFICIENT

Considerable emphasis has been placed by certain investigators in natural illumination upon the "uniformity coefficient." This coefficient is defined as the ratio of the maximum illumination to the minimum observed in the working plane of a room. This coefficient is an important measure of the illumination of a room. It is desirable that it be as small as possible. This coefficient is formulated after one of the rules of artificial lighting given in the American Code of Lighting School Buildings, which specified that "In a classroom at the desk tops the ratio of the maximum intensity of artificial illumination to the minimum intensity of artificial illumination, measured in foot candles, shall be less than four." Values observed for this coefficient in natural lighting usually are much in excess of this minimum of four prescribed in artificial lighting.

TABLE 15.—*Hourly values of the uniformity coefficient—Ratio of the maximum mean illumination for any desk to the minimum observed for any other desk in the same room*

Cloud class	Uniformity coefficient at the indicated hours							
	All hours	9.40	10.40	11.40	12.40	1.40	2.40	3.40
ROOM NO. 107—SOUTHEAST EXPOSURE—DESKS NOS. 1-6								
0	10.9	8.2	12.4	13.8	12.1	10.1	9.6	9.9
2	12.0	7.9	15.0	14.8	13.0	11.5	11.6	10.0
5	15.8	16.3	17.9	17.0	14.2	14.7	13.8	16.8
8	18.1	17.0	22.0	19.9	17.5	16.2	19.1	15.3
10	18.9	14.4	19.1	19.8	18.5	19.6	19.5	21.5
A	10.4	8.4	13.3	15.0	13.1	12.7	10.1	10.1
B	13.8	13.4	14.6	17.4	13.6	11.8	13.5	12.3
C	15.1	11.0	17.8	17.4	13.3	15.8	15.4	14.9
ROOM NO. 104—NORTHWEST EXPOSURE—DESKS NOS. 7-12								
0	8.5	5.7	5.4	5.8	6.5	8.5	11.4	16.5
2	9.4	5.8	6.1	6.3	8.0	9.4	12.2	17.9
5	11.4	8.5	7.6	8.0	8.3	11.8	14.7	20.8
8	13.6	12.4	11.2	12.0	12.1	14.3	16.3	17.1
10	14.0	13.2	13.4	13.4	13.7	14.3	14.7	15.4
A	9.0	6.4	6.4	6.1	7.3	10.0	11.5	15.3
B	11.2	9.4	7.3	9.0	11.8	11.0	13.6	16.2
C	12.5	9.6	10.3	10.7	10.5	13.1	15.4	17.7
ROOM NO. 204—NORTHWEST EXPOSURE—DESKS NOS. 13-18								
0	11.4	6.7	6.3	7.8	8.9	12.1	15.6	22.3
2	12.4	7.0	7.1	8.0	11.0	13.7	17.8	22.5
5	16.4	11.3	11.3	11.8	12.5	15.5	22.3	30.0
8	20.3	18.8	15.6	17.9	16.8	21.6	24.6	26.6
10	22.0	20.4	20.8	22.4	20.7	22.3	25.2	22.5
A	12.2	8.2	7.7	8.1	9.8	13.5	15.4	23.0
B	14.3	11.2	10.1	12.5	11.9	15.8	17.1	21.5
C	17.4	14.9	14.8	15.5	14.3	19.2	22.2	21.0
ROOM NO. 207—SOUTHEAST EXPOSURE—DESKS NOS. 19-24								
0	11.0	19.8	11.3	12.4	10.0	8.6	7.1	7.9
2	12.3	20.3	14.4	14.0	12.3	8.9	7.9	8.1
5	13.9	25.2	12.4	15.0	11.6	11.1	10.5	11.4
8	15.3	18.1	16.1	15.7	14.0	15.3	14.8	12.9
10	15.6	17.2	15.6	16.2	14.4	15.2	15.1	15.6
A	12.0	21.4	13.2	13.1	10.5	9.4	7.9	8.5
B	14.9	23.3	14.9	15.4	11.5	19.1	10.2	9.6
C	14.6	22.6	16.1	16.3	11.5	12.8	10.8	12.4

TABLE 15.—*Hourly values of the uniformity coefficient—Ratio of the maximum mean illumination for any desk to the minimum observed for any other desk in the same room*—Continued

Cloud class	Uniformity coefficient at the indicated hours							
	All hours	9.40	10.40	11.40	12.40	1.40	2.40	3.40
MEAN FOR ROOMS NOS. 107 AND 207—SOUTHEAST EXPOSURE								
0	10.9	14.0	11.8	13.1	11.0	9.4	8.4	8.9
2	12.1	14.1	14.7	14.4	12.6	10.2	9.8	9.0
5	14.9	20.8	15.2	16.0	12.9	12.9	12.2	14.1
8	16.7	17.6	19.0	17.8	15.8	15.8	17.0	14.1
10	17.3	15.8	17.4	18.0	16.4	17.4	17.3	18.6
A	11.9	14.9	13.2	14.0	11.8	11.0	9.0	9.3
B	14.3	18.4	14.8	16.4	12.0	15.4	11.8	11.0
C	14.9	16.8	17.0	16.8	12.4	14.3	13.1	13.6
MEAN FOR ROOMS NOS. 104 AND 204—NORTHWEST EXPOSURE								
0	10.0	6.2	5.8	6.8	7.7	10.3	13.5	19.4
2	10.9	6.4	6.6	7.2	9.5	11.6	15.0	20.2
5	13.9	9.9	9.4	9.9	10.4	13.6	18.5	25.4
8	16.9	15.6	13.4	15.0	14.4	18.0	20.4	21.8
10	18.0	16.8	17.1	17.9	17.2	18.3	20.0	19.0
A	10.6	7.3	7.0	7.1	8.6	11.8	13.4	19.2
B	12.7	10.3	8.7	10.8	11.8	13.4	15.4	18.8
C	15.0	12.2	12.6	13.1	12.4	16.2	18.8	19.4

TABLE 16.—*Monthly values of the uniformity coefficient—Ratio of the maximum mean illumination for any desk to the minimum observed for any other desk in the same room*

Cloud class	Uniformity coefficient for the indicated monthly intervals							
	All months	Oct.[1]	Nov.[1]	Dec.[1]	Jan.[1]	Feb.[1]	Mar.[1]	Apr.[1]
ROOM NO. 107—SOUTHEAST EXPOSURE—DESKS NOS. 1-6								
0	11.2	15.3	10.7	8.8	8.7	9.2	11.1	14.4
2	12.1	17.1	12.3	12.4	8.8	9.6	11.3	13.5
5	15.8	20.8	15.4	13.7	13.1	14.6	15.4	17.8
8	18.8	28.9	19.1	16.6	15.7	16.6	16.7	17.7
10	19.1	26.6	21.1	14.3	17.6	18.9	15.8	19.4
A	11.8	16.1	11.3	9.7	8.1	10.6	10.3	16.3
B	14.4	18.4	12.5	13.1	11.6	13.4	15.4	16.2
C	16.2	--------	15.9	10.5	16.3	16.9	16.5	21.2
ROOM NO. 104—NORTHWEST EXPOSURE—DESKS NOS. 7-12								
0	8.4	10.4	8.5	6.8	7.3	7.6	8.9	9.6
2	9.4	13.7	8.3	7.4	7.3	9.4	9.5	10.2
5	10.7	16.0	11.0	10.6	8.3	9.6	8.5	10.7
8	14.0	18.1	15.2	13.9	11.9	12.6	10.8	15.7
10	14.6	19.0	17.8	14.1	14.2	14.5	10.7	11.9
A	9.1	11.7	8.9	7.3	7.2	11.1	7.8	9.4
B	10.5	11.9	8.5	10.3	11.0	9.3	9.6	12.7
C	12.9	--------	15.1	10.8	9.5	16.2	11.2	14.5
ROOM NO. 204—NORTHWEST EXPOSURE—DESKS NOS. 13-18								
0	10.9	15.8	10.7	7.5	9.1	9.2	12.5	11.8
2	12.4	21.2	10.8	9.3	9.0	12.2	11.4	13.1
5	15.4	25.3	16.8	14.0	10.1	15.5	11.8	14.3
8	20.5	30.6	23.9	18.0	15.4	16.5	16.1	23.1
10	22.9	32.8	28.8	21.2	20.8	21.0	16.6	18.9
A	12.4	18.7	12.0	8.5	9.0	14.9	10.0	13.5
B	13.5	18.6	10.2	12.8	12.9	9.9	14.5	15.4
C	18.2	--------	20.5	15.3	14.8	23.6	15.9	18.9
ROOM NO. 207—SOUTHEAST EXPOSURE—DESKS NOS. 19-24								
0	10.1	12.4	10.6	8.2	8.9	9.9	10.7	9.7
2	11.2	14.1	12.2	11.4	8.9	11.6	11.1	9.4
5	13.5	15.2	13.8	13.1	11.8	14.6	11.4	14.3
8	15.2	16.3	15.1	14.1	14.5	15.5	14.1	16.8
10	15.2	16.2	17.2	13.9	15.2	15.7	13.8	14.6
A	11.1	14.4	11.9	9.2	8.2	12.1	10.0	12.0
B	12.5	13.6	14.8	12.0	8.4	13.6	12.2	13.2
C	14.0	--------	16.0	12.4	15.8	12.1	14.8	13.0

[1] Interval ending on the 15th day of the indicated month.

TABLE 16.—*Monthly values of the uniformity coefficient—Ratio of the maximum mean illumination for any desk to the minimum observed for any other desk in the same room*—Continued

Cloud class	Uniformity coefficient for the indicated monthly intervals							
	All months	Oct.[1]	Nov.[1]	Dec.[1]	Jan.[1]	Feb.[1]	Mar.[1]	Apr.[1]
MEAN FOR ROOMS NOS. 107 AND 207—SOUTHEAST EXPOSURE								
0	10.6	13.8	10.6	8.5	8.8	9.6	10.9	12.0
2	11.7	15.6	12.2	11.9	8.8	10.6	11.2	11.4
5	14.6	18.0	14.6	13.4	12.4	14.6	13.4	16.0
8	17.0	22.6	17.1	15.4	15.1	16.0	15.4	17.2
10	17.2	21.4	19.2	14.1	16.4	17.3	14.8	17.0
A	11.5	15.2	11.6	9.4	8.2	11.4	10.2	14.2
B	13.5	16.0	13.6	12.6	10.0	13.5	13.8	14.7
C	15.1	--------	16.0	11.4	16.0	14.5	15.6	17.1
MEAN FOR ROOMS NOS. 104 AND 204—NORTHWEST EXPOSURE								
0	9.7	13.1	9.6	7.2	8.2	8.4	10.7	10.7
2	10.9	17.4	9.6	8.4	8.2	10.8	10.4	11.6
5	13.0	20.6	13.9	12.3	9.2	12.6	10.2	12.5
8	17.3	24.4	19.6	16.0	13.6	14.6	13.4	19.4
10	18.7	25.9	23.3	17.6	17.5	17.8	13.6	15.4
A	10.7	15.2	10.4	7.9	8.1	13.0	8.9	11.4
B	12.0	15.2	9.4	11.6	12.0	9.6	12.0	14.0
C	15.5	--------	17.8	13.0	12.2	19.9	13.6	16.7

[1] Interval ending on the 15th day of the indicated month.

In Tables 15 and 16 are given the hourly and monthly average values of the uniformity coefficient, each classified according to clouds. These values are also shown graphically in Figure 36. The values in these tables are computed from the maximum and minimum mean illuminations given for each hour or month in Tables A and B, respectively, in the appendix. The monthly values in Table A are means of the values for all 7 hours for each month, and the hourly values in Table B are the means for each hour of the 7 values for 7 months, October to April. As should be expected, these values for the uniformity coefficient are larger than the corresponding ones of the distribution coefficient, since they are computed from the highest and lowest values of the illumination in the room while the distribution coefficient is computed from the values of the illumination observed directly across the room in a line perpendicular to the plane of the windows.

DIURNAL VARIATIONS

For the hourly values shown in Table 15, the behavior of the coefficient is quite different in the case of the two rooms 104 and 204, with a northwest exposure (section F, fig. 36), from that shown for the other two rooms, 107 and 207, with a southeast exposure (section E, fig. 36). For the rooms with the northwest exposure, in the case of

zero clouds and for all of the thin clouds and especially class A, there is a material progessive increase from 9.40 a. m. to 3.40 p. m., the late afternoon value being a trifle more than three times the early forenoon

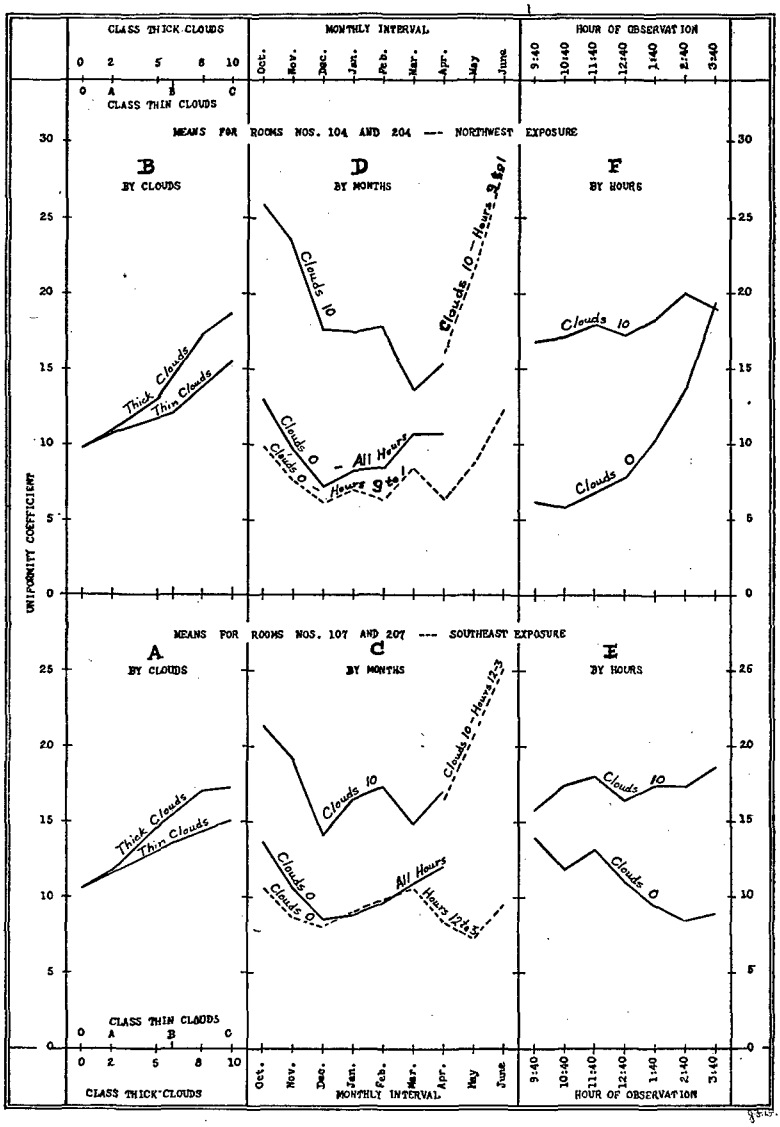


FIGURE 36.—Uniformity coefficient. Ratio of maximum illumination to the minimum in each room. Values arranged by hours, months, and class of clouds for each of two directions of window exposure

value. For the rooms with the southeast exposure, the reverse is true, the coefficient for zero clouds decreasing as the day advances from 9.40 a. m. to 3.40 p. m. The forenoon value, however, is less than

twice the afternoon value, the former corresponding to a time two and one-third hours prior to noon, and the latter corresponding to a time three and two-thirds hours after noon.

For ten-tenths clouds, the coefficient is approximately constant, there being perhaps a slight increase in the coefficient as the day advances. This is the case for each of the exposures, and, if there is any trend under these cloud conditions, it agrees with the trend for zero clouds in the case of the rooms with the northwest exposure and opposite to the trend for zero clouds for the rooms with the southeast exposure.

SEASONAL CHANGES

The monthly averages of the uniformity coefficient are given in Table 16, and some of the values of this table are shown graphically in sections C and D of figure 36, together with certain other values to be explained presently. One of the important characteristics of the values shown in Table 16 is the minimum in December corresponding to few clouds, particularly zero clouds and class A clouds. This seasonal drop is about the same for each of the two exposures, northwest and southeast, and in each case the minimum comes in December. In the case of ten-tenths clouds there is considerable change, but the nature of this change is not so much a cyclical seasonal fluctuation as a gradual decline throughout the period from October to April.

It was, therefore, felt desirable to obtain values for this coefficient for the two additional months, May and June, during which observations were made but not used in computing the absolute values of the illumination owing to an uncertainty in the transmission of the color filter of the illuminometer. The desired values of the uniformity coefficient for these two months can be obtained from the values tabulated for the "illumination ratio" in Table D. Other things being the same, values for the uniformity coefficient derived from the illumination ratio are strictly comparable with values derived from the actual illumination. This is true because for any particular cloud condition, the same values of outside illumination which were used in computing the mean illumination ratio recognized as the maximum for one desk in the room were also used in computing the other illumination ratio recognized as the minimum for another desk in the same room. By dividing one of these two illumination ratios by the other, the influence of the value of the outside illumination disappears, thereby leaving a ratio equivalent in value to that which would be obtained by dividing the maximum mean value of the actual illumination by the corresponding minimum.

It is unfortunate, however, that for the values of the illumination ratio tabulated in Table D, other things are not the same as those given for the actual illumination in Table A. The differences are of two kinds.

(1) The values in Table A are the means of 7 quantities, 1 for each of the 7 hours of the day at which observations were made, while in Table D the values are the means of the quantities for 4 or 5 hours during which the room was free from direct sunshine, those hours depending upon the direction of exposure. (See footnote 1, Table D, p. 117.)

(2) Some of the values used in the preparation of Table A were excluded from Table D because of excessive change in outside illumination between the beginning and end of each hourly series of observations. All of the values used in Table D were used in the preparation of Table A, but the reverse is not true.

TABLE 17.—*Monthly values of the uniformity coefficient computed from the illumination ratios* [1]*—Ratio of the maximum mean value of the illumination ratio for any desk to the minimum observed for any other desk in the same room*

Cloud class	Uniformity of the illumination ratio for the indicated monthly intervals									
	All months	Oct.[2]	Nov.[2]	Dec.[2]	Jan.[2]	Feb.[2]	Mar.[2]	Apr.[2]	May [2]	June [2]
ROOM NO. 107—SOUTHEAST EXPOSURE—DESKS NOS. 1-6										
0	10.3	11.9	9.9	8.9	9.8	10.9	11.9	9.7	8.4	11.0
2	12.0	12.9	12.9	12.1	11.7	12.4	10.4	11.3	9.0	15.1
5	15.1	15.3	8.5	14.1	15.8	16.0	12.5	12.5	13.4	28.0
8	19.4	23.3	17.8	15.2	19.1	20.3	14.1	15.8	24.8	24.5
10	22.8	30.7	21.1	18.8	20.2	21.8	16.6	18.3	25.7	32.3
A	12.3	11.9	11.0	9.0	10.6	15.3	11.1	15.2	9.2	17.8
B	12.0	12.5	--------	11.9	11.8	15.9	11.9	15.4	14.8	13.5
C	16.6	--------	15.2	14.3	10.1	18.0	13.1	17.5	18.6	26.4
ROOM NO. 104—NORTHWEST EXPOSURE—DESKS NOS. 7-12										
0	6.7	7.8	6.2	6.0	6.2	5.2	6.6	5.5	7.4	9.4
2	7.9	9.5	9.2	6.7	6.5	8.7	6.6	6.4	8.1	9.7
5	9.9	13.0	9.2	9.2	8.6	6.9	9.7	7.1	14.0	11.0
8	14.3	15.2	17.3	14.2	12.1	12.3	11.8	11.5	13.7	20.5
10	15.7	17.2	17.6	14.8	15.2	14.8	11.2	11.5	17.3	21.3
A	7.8	10.0	8.7	6.4	6.1	8.8	5.8	7.4	7.4	10.0
B	10.0	10.4	7.2	8.5	9.2	7.7	7.6	10.8	14.1	14.8
C	13.1	--------	17.4	10.9	9.4	12.7	9.4	12.9	13.8	18.4
ROOM NO. 204—NORTHWEST EXPOSURE—DESKS NOS. 13-18										
0	9.5	12.1	8.8	6.2	7.9	7.4	10.4	7.4	10.0	15.2
2	10.9	16.1	9.5	8.4	7.4	10.6	8.2	8.6	11.8	17.5
5	13.7	19.4	14.9	12.5	8.5	10.3	9.9	9.1	18.2	20.5
8	21.2	26.4	26.0	17.1	16.1	17.0	17.3	22.5	20.8	27.7
10	25.1	35.0	27.2	21.8	20.7	21.6	17.2	20.6	25.8	35.6
A	10.7	14.6	9.9	7.7	7.3	12.1	7.6	9.0	9.7	18.7
B	13.6	15.8	7.9	10.1	10.3	8.1	12.8	13.8	19.7	23.5
C	19.8	--------	22.9	15.5	15.7	18.6	14.1	18.7	20.4	32.3
ROOM NO. 207—SOUTHEAST EXPOSURE—DESKS NOS. 19-24										
0	7.8	9.3	7.4	7.0	8.1	8.7	9.2	7.0	5.9	8.0
2	9.1	10.4	9.2	8.5	9.2	11.3	8.9	8.3	7.2	8.8
5	11.0	14.6	9.5	11.0	9.9	11.7	10.6	10.8	11.1	9.9
8	14.0	16.4	16.9	8.0	15.0	15.2	11.6	14.1	13.8	14.7
10	16.0	16.1	17.2	15.2	16.7	16.7	13.9	14.4	15.5	18.0
A	8.9	10.6	8.1	7.3	7.8	11.6	8.8	7.3	7.7	10.9
B	9.8	10.0	--------	10.4	8.7	16.4	9.5	11.3	11.2	10.5
C	12.4	--------	10.3	11.6	9.3	13.7	12.4	13.3	13.4	15.3

[1] The mean monthly values of the illumination ratio cover only the hours free from direct sunshine on the windows.

[2] Interval ending on the 15th day of the indicated month.

TABLE 17.—*Monthly values of the uniformity coefficient computed from the illumination ratios* [1]*—Ratio of the maximum mean value of the illumination ratio for any desk to the minimum observed for any other desk in the same room*—Continued

Cloud class	Uniformity of the illumination ratio for the indicated monthly intervals									
	All months	Oct.[2]	Nov.[2]	Dec.[2]	Jan.[2]	Feb.[2]	Mar.[2]	Apr.[2]	May [2]	June [2]
MEAN FOR ROOMS NOS. 107 AND 207—SOUTHEAST EXPOSURE										
0	9.1	10.6	8.6	8.0	9.0	9.8	10.6	8.4	7.2	9.5
2	10.5	11.6	11.0	10.3	10.4	11.8	9.6	9.8	8.1	12.0
5	13.1	15.0	9.0	12.6	12.8	13.8	11.6	11.6	12.2	19.0
8	16.7	19.8	17.4	11.6	17.0	17.8	12.8	15.0	19.3	19.6
10	18.8	23.4	14.2	17.0	18.4	19.2	15.2	16.4	20.6	25.2
A	10.6	11.2	9.6	8.2	9.2	13.4	10.0	11.2	8.4	14.4
B	12.2	11.2	--------	11.1	10.2	16.2	10.7	13.4	13.0	12.0
C	14.5	--------	12.8	13.0	9.7	15.8	12.8	15.4	16.0	20.8
MEAN FOR ROOMS NOS. 104 AND 204—NORTHWEST EXPOSURE										
0	8.1	10.0	7.5	6.1	7.0	6.3	8.5	6.4	8.7	12.3
2	9.4	12.8	9.4	7.6	7.0	9.6	7.4	7.5	10.0	13.6
5	11.8	16.2	12.0	10.8	8.6	8.6	9.8	8.1	16.1	15.8
8	17.7	20.8	21.6	15.6	14.1	14.6	14.6	17.0	17.2	24.1
10	20.4	26.1	22.4	18.3	18.0	18.2	14.2	16.0	21.6	28.4
A	9.3	12.3	9.3	7.0	6.7	10.4	6.7	8.2	8.6	14.4
B	11.8	13.1	7.6	9.3	9.8	7.9	10.2	12.3	16.9	19.2
C	16.5	--------	20.2	13.2	12.6	15.6	11.8	15.8	17.1	25.4

[1] The mean monthly values of the illumination ratio cover only the hours free from direct sunshine on the windows.

[2] Interval ending on the 15th day of the indicated month.

Values of the uniformity coefficient computed from the values of the illumination ratio tabulated in Table D are given in Table 17, and part of these are graphed (dotted lines) in sections C and D of Figure 36. In this figure there are shown the mean values for zero clouds for each of the two exposures for the entire period of nine months, October to June. Each line is labeled by the particular hours included in the mean. For rooms 107 and 207 (section C) the hours are 12.40 to 3.40, while for rooms 104 and 204 (section D) the hours are 9.40 to 1.40. The other curves for zero clouds in these two sections, C and D, marked "all hours" are the values given in Table 16, obtained from the values of actual illumination given in Table A.

For ten-tenths clouds there are shown in the figure (dotted line) only the values for the three months April, May, and June which were derived from the illumination ratio. The other values for ten-tenths clouds for the months October to March are omitted from the graphs, because they duplicate fairly accurately the values derived from the actual illumination which are shown by the solid line in the graph.

In a continuation, therefore, of the discussion of the shape of the seasonal curve of the uniformity coefficient for ten-tenths clouds, it is seen from Figure 36 that this change is a large cyclical fluctuation with a midwinter or perhaps a late winter minimum.

VARIATIONS CAUSED BY CLOUDS

Clouds have a large influence upon the uniformity coefficient and this influence is not the same under all circumstances. The average influence over the period of seven months, October to April (the values are taken from Table 16 and were computed from the actual illumination, thereby including all seven hours of the day), is shown in sections A and B of Figure 36. The values of the coefficient for both the thick clouds and the thin clouds are represented. From the figure it is seen that the thick clouds influence the coefficient more than the thin ones. The average increase in the coefficient caused by the clouds apparently is quite proportional to the increase in cloudiness, at least in so far as the latter can be measured by the cloud classes adopted. On the average the value of the coefficient for ten-tenths thick clouds for the southeast exposure is 162 per cent of the value for zero clouds, and for the northwest exposure it is 193 per cent, the mean being 178 per cent. For the thin clouds, the values of the coefficient for class C clouds for the two exposures are 142 per cent and 160 per cent, respectively, the mean being 151 per cent.

In a consideration of the individual variations in the uniformity coefficient which are caused by clouds, it is seen that whenever the uniformity coefficient is at a minimum, the value of the coefficient for ten-tenths clouds is about twice (and sometimes more) that for zero clouds. This is true without regard to whether the minimum appears in the monthly tabulation, such as in December and January in Table 16 for either exposure, or in the hourly tabulation in Table 15, such as at 3.40 p. m. for rooms 107 and 207 or at 9.40 a. m. for rooms 104 and 204. At other times (with one exception to be presented next) the influence of clouds upon the coefficient is such that the value of the coefficient for ten-tenths clouds is only about one and one-half times that for zero clouds. For rooms 107 and 207 there is not much increase in the coefficient from eight-tenths clouds to ten-tenths clouds.

The peculiar exception to the rule mentioned in the preceding paragraph appears in the hourly tabulation, Table 15. It occurs at 9.40 a. m. for rooms with a southeastern exposure, 107 and 207, and at 3.40 p. m. for rooms with a northwestern exposure. These occasions are times at which the sun shines on the windows (or the walls containing them), admitting light to the rooms under consideration. On these two occasions, starting with the value prevailing for zero clouds the coefficient increases with this cloudiness until about five-tenths clouds are reached; the increase in the coefficient is about 30 per cent to 50 per cent. Beyond this point the coefficient decreases until ten-tenths clouds are reached, when the value of the coefficient

for ten-tenths clouds is about the same as that for zero clouds. In other words, for these particular occasions the uniformity coefficient has a maximum corresponding to about five-tenths clouds, the beginning and ending values corresponding to zero and ten-tenths clouds being about equal.

TABLE 18.—*Ratio of the mean uniformity coefficient for measures of two kinds (desk illumination and illumination ratio) to the corresponding maximum-minimum-sky-vault ratio for the same room, derived from the mean of the tabular values of the coefficient for the five classes of thick clouds given in Tables 16 and 17*

Room No.	Exposure	Floor	Desks Nos.	Sky vault in square degrees			Mean uniformity coefficient, derived from—		Ratio of mean uniformity coefficient to corresponding sky-vault ratio	
				Maximum	Minimum	Ratio	Desk illumination [1] (7 months)	Illumination ratio [2] (9 months)	Desk illumination [1] (7 months)	Illumination ratio [2] (9 months)
1	2	3	4	5	6	7	8	9	10	11
107	East	First	1–6	1,830	82	22.3	15.4	15.9	0.69	0.71
104	West	do	7–12	1,748	180	9.7	11.4	10.9	1.17	1.12
204	do	Second	13–18	2,108	120	17.6	16.4	16.1	.93	.91
207	East	do	19–24	2,378	225	10.6	13.0	11.6	1.23	1.09
Mean									1.00	.96

[1] Monthly values of the desk illumination are based upon the means of values for 7 hours.
[2] The mean monthly values of the illumination ratio cover only 4 or 5 hours free from direct sunshine on the windows.

INFLUENCE OF VISIBLE SKY VAULT

The question naturally arises as to whether there is any significant connection between the uniformity coefficient and the extent of the sky visible from the various desks in the room. Data on this subject are given in Table 18. In the fifth and sixth columns of the table are given the maximum value and the minimum value of the sky vault visible from any of the six desks upon which illumination measurements were made in each room. The sky vault is measured in square degrees, a square degree being an area in the shape of a square 1° on each side. The values in Table 18, columns 5 and 6, are taken from Table 1 and apply to the date June 20, 1924. They are the largest and smallest values observed for any of the six desks, and were so selected without regard as to whether or not they applied to the respective desks having the maximum and minimum values of the illumination from which the uniformity coefficient was derived. In the seventh column of the table there is given for each room the ratio of the maximum sky vault to the minimum. This ratio is a quantity that might be termed "the sky-vault uniformity coefficient," since it corresponds with the uniformity coefficient of the illumination, and which it is desired to compare with the uniformity coefficient.

In the eighth and ninth columns of Table 18 are given two values of the uniformity coefficient itself for each of the rooms. The first of these is derived from Table 16 and therefore represents the mean of the actual illumination for seven hours each day for a period of seven months. The second is derived from Table 17 which in turn was derived from the illumination ratio and therefore represents only 4 or 5 hours free from direct sunshine each day for a period of 9 months. In each case the value given in Table 18 is the unweighted mean of the five values of the coefficient for the five classes of thick clouds (including zero clouds); these five values are given in the second column of Tables 16 and 17, being the columns of means in each of the respective tables. The agreement between the two values of the coefficient for each room given in columns 8 and 9 of Table 18 is remarkably good when it is realized that they were computed by quite different methods and represent different types of data. Additional values comparable with those in column 8 were also computed. These were the mean uniformity coefficient based upon all eight classes of clouds given in Table 16 in place of only five classes; also the coefficient based upon the general mean illumination given in Public Health Bulletin 159, without reference to the number of clouds or their classification. Each of these additional methods gives values quite similar in size to those given in column 8 of Table 18.

By dividing the values of the uniformity coefficient given in columns 8 and 9 of Table 18 by the sky-vault ratio given in column 7, there are obtained the new ratios presented in columns 10 and 11. There does not seem to be a suitable name to apply to these ratios unless "uniformity sky-vault ratio" is satisfactory; but this, however, is quite similar to the term "sky-vault uniformity coefficient" used to represent the quantities in column 7 of the table. These values in column 10 show the dependence of the uniformity coefficient upon the sky vault visible at the various desks in the room. They show that if the "sky-vault uniformity coefficient" is large, the uniformity coefficient can be expected to be large also. Although there is a certain amount of variation from room to room in the ratios given in columns 10 and 11, they are not materially different from unity, and the mean of the four values for the four rooms is exceedingly close to unity. For the values representing seven months (column 10) the mean ratio is 1.00; and for the other values representing nine months and the hours free from direct sunshine, the mean ratio is 0.96.

It would seem therefore that on the average a fairly accurate estimate of the uniformity coefficient of a room is given by the ratio of the maximum and minimum values of the sky vault visible in the working plane.

LOCATION OF MAXIMUM AND MINIMUM ILLUMINATION IN WORKING PLANES

An interesting study in connection with the uniformity coefficient is the changes of the location of the maximum and minimum illumination from one desk to another in connection with changes in other factors such as cloudiness and hour of the day. For room 107 with a southeastern exposure, the maximum mean illumination at the time of zero clouds occurs on desk No. 2 for each of the seven hours of the day at which observations were made; and for ten-tenths clouds the maximum occurs at desk No. 1 for each of the seven hours. This same thing is approximately true with the thin clouds, class A clouds in general giving desk No. 2, and class C clouds generally giving desk No. 1 the maximum mean illumination. The portion of the sky visible from desk No. 1 is farther north (or perhaps northeast would be a better description of the direction) than the portion of the sky visible from desk No. 2.

For the minimum illumination the same conclusion can be drawn. In the forenoon the minimum illumination in room 107 shifts from desk No. 6 for few clouds to desk No. 4 for ten-tenths clouds; in the afternoon, it remains at desk No. 6. The portion of the sky supplying light to desk No. 6 is farther north than the portion lighting desk No. 4. In other words, the portion of the sky supplying light to the desk having the maximum illumination at the time of ten-tenths clouds is slightly more northward in the eastern sky than it is when the sky is totally clear; and for the desk having the minimum illumination it is slightly farther south for ten-tenths clouds than it is for zero clouds.

The same conclusion is suggested for the other three rooms included in this study, whenever the observations have any indication on this question. Quite frequently the values of the illumination on adjacent desks are so dissimilar that the difference in brightness for different portions of the sky is not sufficient to cause the maximum or minimum inside illumination to shift from one desk to another, i. e., the maximum or minimum will frequently remain at one particular desk for all cloud conditions. In these other three rooms there are a few occasions when the observations apply on this point. For the other room with a southeast exposure, No. 207, the minimum shifts in the forenoon from desk No. 19 to desk No. 21 as the clouds increase from zero to ten-tenths. The portion of the sky lighting desk No. 19 is farther north than that lighting desk No. 21; the change from one portion of the sky for one cloud class to another portion for another cloud class is, therefore, again southward in the case of a minimum.

For the rooms with a northwest exposure, Nos. 104 and 204, the location of the minimum in each room remains at one particular

desk as the clouds increase from zero to ten-tenths. In the late afternoon, the maximum, however, shows a tendency to shift from desk No. 12 to No. 11 in room 104 and from desk No. 18 to No. 17 in room 204. In each of these cases the shift of the portion of the sky supplying light for a maximum is again northward as the number of clouds increases from zero to ten-tenths.

It is not obvious what causes the shifting of the maximum or minimum illumination from one desk to another as the percentage of cloudiness increases. Two possible causes are recognized. It is probably that, at times, one cause applies, and at other times the other cause applies. The first of these possible causes, if real, is of some importance. The shifting northward in the sky for a maximum illumination as the clouds increase in number, may be due to increased reflection of light by the clouds as a result of a smaller angle of reflection. The other possible cause is that at certain times of the day (such as at 9.40 a. m. for rooms with a southeastern exposure, and at 3.40 p. m. with a northwestern exposure) the normal relationship may be completely destroyed or distorted by the admission of direct sunlight into the room to shine upon the desk tops and the floor from whence it is reflected to the walls and ceiling to be reflected again to desk tops in the far corners of the room. This might produce an abnormal situation which, of course, would subside as the direct sunlight would cease to shine into the room.

VISIBLE SKY VAULT AND ILLUMINATION

INTRODUCTION

In discussing the uniformity coefficient in the previous section, (p. 86), it was shown that there is a considerable connection between that measure and the extent of the sky vault visible from the various desks in the room. At that time it was stated that on the average a fairly accurate estimate of the uniformity coefficient of a room can probably be obtained by getting the ratio of the maximum and minimum values of the sky vault visible at various points in the working plane. There obviously is an intimate relationship existing between the natural lighting at various points in the working plane of a room and the area of the sky vault which is visible from each of these points. It seems desirable, therefore, to determine more fully the nature of this relationship.

TABLE 19.—*Relation of mean desk illumination to visible sky vault—Ratio of mean desk illumination [1] in foot-candles to the visible sky vault in square degrees for each desk, and a comparison of these ratios between desks far from the windows and those near the windows*

Room No.	Desk No.	Mean illumination in foot-candles [1]	Visible sky vault in square degrees June 20, 1924	Foot candles per square degree	Proximity of desks to windows	Mean for three desks	Ratio, far to near
1	2	3	4	5	6	7	8
107	1	158.6	1,830	0.087			
107	2	165.1	1,718	.096	Near	0.107	
107	3	139.9	1,022	.137			1.15
107	4	12.9	128	.101			
107	5	15.2	135	.113	Far	.123	
107	6	12.8	82	.156			
104	7	10.8	345	.031			
104	8	11.2	352	.032	Far	.036	
104	9	8.2	180	.046			.71
104	10	47.2	968	.049			
104	11	85.4	1,748	.049	Near	.051	
104	12	89.3	1,605	.056			
204	13	8.3	284	.029			
204	14	8.3	304	.027	Far	.033	
204	15	5.3	120	.044			.85
204	16	32.7	938	.035			
204	17	79.4	2,108	.038	Near	.039	
204	18	68.1	1,601	.043			
207	19	11.5	225	.051			
207	20	15.6	330	.047	Far	.048	
207	21	13.8	308	.045			.77
207	22	107.2	1,410	.076			
207	23	141.9	2,378	.060	Near	.062	
207	24	105.4	2,092	.050			
Means:							
Rooms 107 and 207							.96
Rooms 104 and 204							.78

[1] Taken from Table 4, Public Health Bulletin No. 159. These mean values represent all cloud conditions, all hours (9.40 a. m. to 3.40 p. m.), and all months (October to April).

AVERAGE ILLUMINATION AND SKY VAULT

The solution of a simple phase of this problem is given in Table 19. In column 3 of the table there is given for each of the 24 desks the mean of all of the observed values of the illumination. These are the general averages published in Table 4 on page 30 of Public Health Bulletin 159, and are means of all the observations made each hour from 9.40 a. m. to 3.40 p. m., from September 17, 1923, to April 15, 1924, under the various conditions of cloudiness existing at the times of observation. The values for all of the desks are comparable since each desk has just as many observations of any particular set of conditions as any other desk.

In the next, or fourth column, of the table (No. 19, this bulletin) is given in square degrees the area or extent of the sky vault visible from each of the desks. These values are the results of measures made on June 20, 1924, a few days after the close of the series of

observations, and at a time when surrounding (elm) trees were in full summer foliage. They were measured by means of a sterogoniometer [13] by estimating the number of graduated squares on the surface of a convex mirror which were covered by the image of the sky vault visible at the location of the mirror. The size of the squares graduated on the mirror were rather carefully calibrated (by the method of reflected images); each square was found to cover on the average an area of 75 square degrees. The values given for the area of the sky vault may possess considerable error (due to some unknown error in the calibration) but relative to each other they are believed to have a fairly high degree of accuracy, probably within 10 per cent. The error of a reading surely is considerably less than 10 per cent, but because in some rooms (particularly room No. 107) a large portion of the window view is eclipsed by trees, large differences in the visible sky vault may happen over short intervals of time or result from small causes. Furthermore, an accurate measure for one occasion may not be a true representative of average conditions over a period of time.

In the fifth column of Table 19 is given the average illumination in foot-candles per square degree of sky vault visible at each of the desks on June 20, 1924. These values, ranging from a minimum of 0.027 for desk No. 14 to a maximum of 0.156 for desk No. 6, give some idea of the size of the quantity obtained, but can not be strictly accurate because of the fact that the sky vault measures apply to one particular time when the trees were in approximately full summer foliage while the illumination measures apply to the entire interval from September 17 to April 15 during a large portion of which period the trees were in winter foliage thereby providing a larger area of visible sky vault than in summer. This fact alone probably is the cause of the disagreement to be found later between the results for room 107 and the other three rooms. It is to be noticed that for three of the rooms, Nos. 104, 204, and 207, the values of the illumination per square degree show considerable agreement with each other, while the values for the other room, No. 107, are considerably higher.

FAR-NEAR-SKY-VAULT RATIO

In the seventh column of the table there is given for each room a mean of the values for the three desks near the windows, and a mean for the three desks far from the windows. For all of the rooms except No. 107, the values for the desks far from the windows are smaller than those for the desks near the windows. A ratio of these values given in column 7, taken in the order of far to near, gives the

[13] Described in the Zeitschrift für Instrumenten-Kunde, Bd. 4, pp. 343-347, 1884.

values shown in column 8. Let these values be called the "far-near-sky-vault ratio," or perhaps the "far-near ratio" for short. This ratio shows relatively how much light per square degree of visible sky vault is received at the back of the room as compared to that received per square degree at the front of the room. For three of the rooms the values of the far-near-sky-vault ratio is less than unity, while for room 107 (the room with high windows, a southeastern exposure, and flooded much of the time by direct sunlight when the window shades are open as was the case when all of these observations were made) the value is above unity.

This far-near ratio requires more careful scrutiny. Is it a quantity that on the average is approximately unity, or does it vary? Does it at times have a value approximately unity and under other circumstances a value less than unity? If it is not constant, what are the factors causing its variation? This quantity or ratio is a very important one, because an adequate knowledge of it and its variations will make it possible to accomplish a task that has never been satisfactorily done before, i. e., estimate the natural illumination at any point in a room from the plans of a building before the structure is erected.

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TABLE 20.—*Ratio of October illumination to visible sky vault, arranged by cloud classes, and computed for both "original" square degrees and "reduced" square degrees from sky-vault measurements made June 20, 1924; also a comparison of these ratios between desks far from the windows and those near the windows*

Cloud class	Desk illumination per square degree of visible sky vault						Group means for far-near ratio	
	"Original" square degrees			"Reduced" square degrees				
	3 desks near windows	3 desks far from windows	Far / Near	3 desks near windows	3 desks far from windows	Far / Near	Original square degrees	Reduced square degrees
1	2	3	4	5	6	7	8	9
Room 107—Southeast exposure							Mean for rooms 107 and 207	
0	0.118	0.116	0.98	0.198	0.521	2.63	0.85	2.14
2	.110	.095	.86	.184	.426	2.32	.78	1.93
5	.126	.091	.72	.212	.410	1.93	.68	1.66
8	.156	.084	.54	.263	.379	1.44	.56	1.35
10	.078	.048	.61	.132	.215	1.63	.60	1.45
A	.131	.119	.91	.219	.537	2.45	.78	1.94
B	.160	.131	.82	.270	.591	2.19	.76	1.84
C								
Room 104—Northwest exposure							Mean for rooms 104 and 204	
0	0.042	0.036	0.86	0.087	0.174	2.00	0.93	2.02
2	.061	.042	.69	.124	.201	1.62	.74	1.62
5	.067	.038	.57	.137	.182	1.33	.59	1.31
8	.068	.033	.49	.139	.155	1.12	.50	1.10
10	.055	.024	.44	.112	.114	1.02	.44	.98
A	.051	.038	.74	.103	.185	1.80	.78	1.76
B	.061	.045	.74	.125	.218	1.74	.78	1.74
C								
Room 204—Northwest exposure							Mean for all 4 rooms	
0	0.032	0.032	1.00	0.071	0.145	2.04	0.80	2.08
2	.046	.036	.78	.102	.166	1.63	.76	1.78
5	.054	.033	.61	.120	.155	1.29	.64	1.48
8	.049	.025	.51	.109	.118	1.08	.53	1.22
10	.045	.020	.44	.101	.094	.93	.52	1.21
A	.039	.032	.82	.086	.149	1.73	.78	1.85
B	.046	.038	.83	.102	.176	1.73	.77	1.79
C								
Room 207—Southeast exposure								
0	0.065	0.047	0.72	0.146	0.241	1.65		
2	.065	.045	.69	.147	.227	1.54		
5	.085	.054	.64	.198	.276	1.39		
8	.072	.042	.58	.168	.212	1.26		
10	.046	.027	.59	.108	.137	1.27		
A	.083	.055	.66	.196	.280	1.43		
B	.096	.067	.70	.226	.339	1.50		
C								

TABLE 21.—*Relation of June "illumination ratio" to visible sky vault, arranged by cloud classes, and computed for both "original" square degrees and "reduced" square degrees from sky-vault measurements made June 20, 1924; also a comparison of these ratios between desks far from the windows and those near the windows*

Cloud class	Illumination ratio (×10,000) per square degree of visible sky vault						Group means for far-near ratio	
	"Original" square degrees			"Reduced" square degrees				
	3 desks near windows	3 desks far from windows	Far / Near	3 desks near windows	3 desks far from windows	Far / Near	Original square degrees	Reduced square degrees
1	2	3	4	5	6	7	8	9
	Room 107—Southeast exposure						Mean for rooms 107 and 207	
0	0.056	0.091	1.62	0.093	0.400	4.30	1.36	3.37
2	.075	.089	1.19	.126	.389	3.09	1.10	2.66
5	.115	.103	.90	.228	.443	1.94	.92	2.00
8	.320	.251	.78	.531	.838	1.58	.70	1.46
10	.404	.225	.56	.679	.991	1.46	.56	1.34
A	.109	.109	1.00	.183	.482	2.63	.95	2.30
B	.106	.135	1.27	.178	.596	3.35	1.08	2.66
C	.362	.236	.65	.608	1.048	1.72	.64	1.56
	Room 104—Northwest exposure						Mean for rooms 104 and 204	
0	0.053	0.048	0.91	0.109	0.227	2.08	0.96	2.08
2	.066	.055	.83	.136	.264	1.94	.84	1.85
5	.091	.070	.77	.185	.334	1.80	.78	1.69
8	.273	.131	.48	.557	.619	1.11	.53	1.16
10	.332	.139	.42	.678	.661	.98	.44	.96
A	.063	.051	.81	.128	.246	1.92	.86	1.89
B	.172	.101	.59	.353	.482	1.36	.62	1.34
C	.241	.118	.49	.492	.560	1.14	.49	1.08
	Room 204—Northwest exposure						Mean for all 4 rooms	
0	0.042	0.043	1.02	0.095	0.198	2.08	1.16	2.72
2	.049	.042	.86	.109	.192	1.76	.98	2.26
5	.080	.062	.78	.182	.287	1.58	.85	1.84
8	.195	.114	.58	.436	.529	1.21	.61	1.30
10	.248	.112	.45	.558	.519	.93	.50	1.15
A	.050	.045	.90	.112	.208	1.86	.90	2.10
B	.131	.084	.64	.293	.390	1.33	.85	2.00
C	.196	.097	.49	.442	.451	1.02	.57	1.32
	Room 207—Southeast exposure							
0	0.034	0.037	1.09	0.078	0.192	2.44	----------	----------
2	.045	.046	1.02	.104	.233	2.24	----------	----------
5	.069	.065	.94	.161	.331	2.06	----------	----------
8	.287	.174	.61	.670	.887	1.32	----------	----------
10	.265	.148	.56	.617	.751	1.22	----------	----------
A	.062	.056	.90	.145	.286	1.97	----------	----------
B	.068	.061	.90	.159	.311	1.96	----------	----------
C	.209	.134	.64	.488	.684	1.40	----------	----------

Additional values of this far-near-sky-vault ratio are given in Tables 20 and 21, and portrayed graphically in Figures 37 and 38. In each of these, however, the values are classified according to degree of cloudiness.

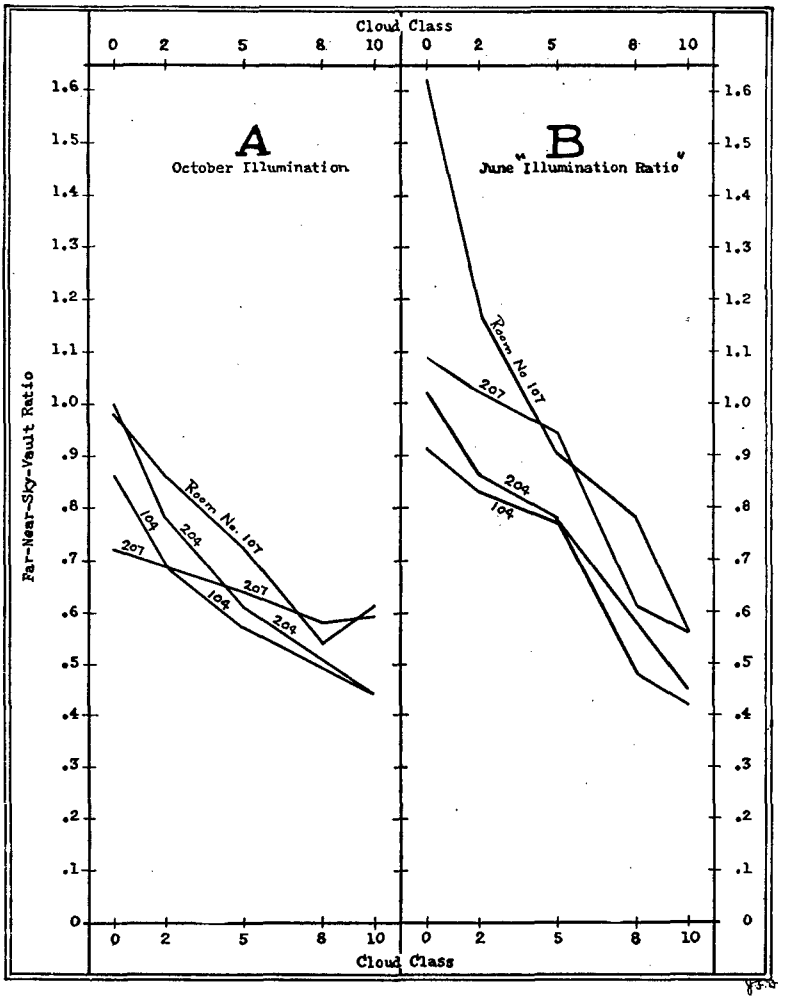

FIGURE 37.—Ratio of foot-candles per square degree between desks far from windows and those near windows ("far-near-sky-vault ratio"). Arranged by clouds as abscissæ; derived from actual illumination for October and from the illumination ratio for June; the values for the sky vault were obtained on June 20, 1924

The values in Table 20 are based upon the observations for the month of October (September 17 to October 15). Owing to the fact that the values of actual illumination were not computed for the May and June periods, October was selected as being the month during the

interval, October to April, for which the foliage of the trees was most like the summer conditions prevailing on June 20, the date upon which the sky vault measures were made. The illumination values used in the preparation of this table represent the means of the seven hourly observations 9.40 a. m. to 3.40 p. m. each day. The values for the

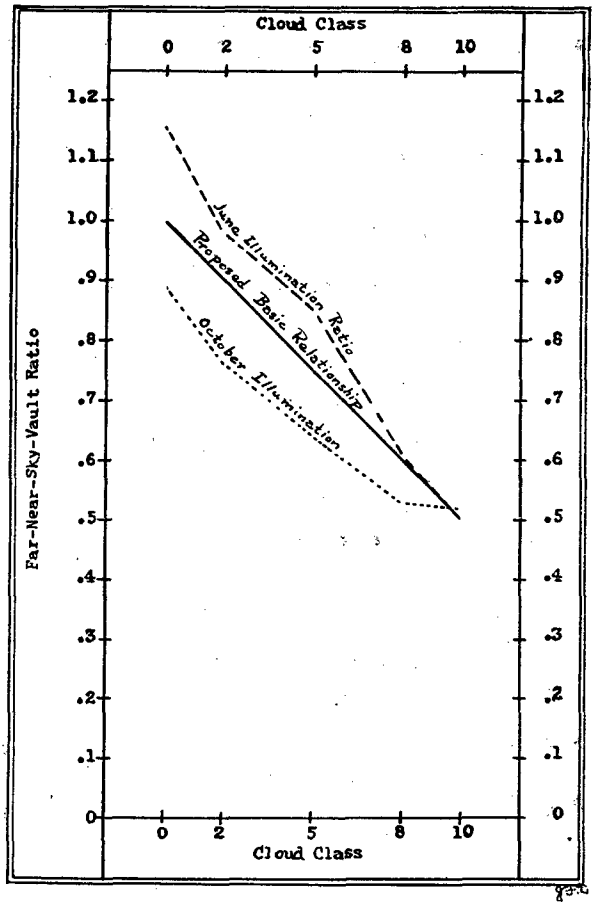

FIGURE 38.—Far-near-sky-vault ratio. Curves for means and proposed theoretical basic relationship. Means of four rooms; arranged by clouds as abscissæ; derived from actual illumination for October and from the illumination ratio for June; sky vault values for June 20, 1924

sky vault are those given in Table 19. They are also given in Table 1. In column 2 of Table 20 is given the mean illumination per square degree for the three desks near the windows in each of the four rooms, a value being given for each cloud class shown in column 1; and in column 3 are given means for the three desks far from the windows in each of the rooms. Column 4 gives a value of the far-near-sky-

vault ratio for each cloud class from the values given in columns 2 and 3. Means of the values in column 4 are given in column 8 for various groups of rooms.

"REDUCED" SQUARE DEGREES

Columns 5, 6, and 7 of Table 20 give values similar to those just described for columns 2, 3, and 4 except that in this case, the basis of comparison is the sky vault measured in "reduced" square degrees. This unit of measure was suggested by Cohn as probably being a better unit for the sky vault than the square degree generally referred to hereinafter as the "original" square degree. The number of reduced square degrees is obtained by multiplying the existing area of visible sky vault expressed in square degrees (or "original" square degrees) by the trigonometric sine of the angle of elevation of the middle of the visible portion. Means of the values of the far-near-sky-vault ratio for reduced square degrees shown in column 7, are given in column 9.

A comparison of the values in Table 20, column 9, for reduced square degrees with those in column 8 for original square degrees shows that the former is a little more than twice the latter. This relation apparently is quite constant. It is desired to point out, however, that this fact has no significance in relation to variations in lighting. The value is constant for all cloud classes for each room, but is not the same for all of the rooms. It is a quantity that results from a particular cross product and quotient of the sky vault values measured in both original square degrees and in reduced square degrees. The method of combination is indicated by the method of computing the far-near-sky-vault ratio in the two cases, but since it has no vital significance to the problem, it will not be explained in detail. Apparently, for the rooms used in this particular study there is no advantage to be gained by using reduced square degrees in preference to original square degrees. Furthermore, the former are more or less of a fiction derived from the latter. For this reason, and because (as will appear later) the constants have a certain desirable form and size when derived from the original square degrees, attention will be directed to this unit of measure for the remainder of this study.

"ORIGINAL" SQUARE DEGREES AND CLOUDS—OCTOBER ILLUMINATIONS

The values of the far-near-sky-vault ratio for thick clouds given for original square degrees in column 4 of Table 20 are portrayed graphically in section A of Figure 37. Four lines are given which show for each of the rooms the variation of the far-near-sky-vault ratio as the clouds increase from zero to ten-tenths. A mean of these four lines for the four rooms for each cloud class is portrayed in the dotted line in Figure 38 (the actual values are given in section

3, column 8, Table 20). This dotted line shows the average relationship noted between clouds and the variation in the number of foot-candles per square degree resulting from passing from desks near the windows to desks back from the windows. It must not be overlooked, however, that these are based upon illumination measurements made in October, and upon sky-vault measurements obtained the following June.

ILLUMINATION FOR JUNE

To get a comparison of this far-near relationship based upon observations of more nearly the same time is believed worth while. Since the latest monthly interval for which the actual illumination was computed was for April (March 16 to April 15), and since the trees did not have summer foliage at that time, it was necessary to use values prepared for illumination ratio. The best month for this purpose was June; i. e., May 16 to June 15. Values based upon the June illumination ratio and similar to those in Table 20 for the October illumination are given in Table 21. The values in column 4 of this table are shown graphically in section B of Figure 37; means are shown in the dashed line of Figure 38, and actual values for these means are given in column 8, section 3 of the table.

In Table 21, the values given in column 4 for one cloud class are on a comparable basis with those given in the same column for the other cloud classes. This also is true for column 7. On the other hand, the values of the illumination ratio per square degree given in columns 2 and 3, and in columns 5 and 6, are not comparable from one cloud class to another. The values given for zero clouds for each of the rooms in Table 21 can be compared, and in like manner the values given for any other cloud class, such as eight-tenths, can be intercompared, but any value in these columns (2, 3, 5, and 6) for one cloud class should not be compared with a value for any other cloud class even though it be in the same column. This is due to the fact that in computing the illumination ratio the denominator is different for each of the cloud classes. When two values for the same cloud class are compared by means of a ratio, such as in columns 4 and 7, the denominator of the illumination ratio cancels out leaving the resulting values of the far-near-sky-vault ratio independent of the outside illumination or any value thereof used in computing the illumination ratio. It is for this reason that all of the values for the far-near-sky-vault ratio can be intercompared even though the other values of the table may not be.

SIGNIFICANCE OF FAR-NEAR-SKY-VAULT RATIO

The curves shown in Figure 38 deserve special consideration. They both represent approximately the same thing, the variation of the

far-near-sky-vault ratio with clouds. One curve is based upon values of the illumination for October, the other for June. In the curve for October, all hours of the day are included, but the curve for June represents only the shaded hours (see p. 51). The former is slightly lower than the latter. This difference might possibly be due to the different hours included in the averages. It might also be partially or entirely due to an actually larger sky vault in October than in the ensuing June, thereby giving values too small for the October results. This would be the case if the 1923 growth of leaves had partially fallen off by October 15, or if the trees had grown and were taller on June 20 than during the preceding October. Both of these possibilities probably did occur. If so, they at least partially explain the difference between the graphs in Figure 38.

If the dotted and dashed lines in Figure 38 are accepted, a mean of them corresponds very closely to a straight line joining the point 1.0 for zero clouds to the point 0.5 for ten-tenths clouds. Such a straight line is shown in the figure. It is assumed that this straight line is as good an estimate of the true relationship under the conditions of the experiment as can be expected from these observations. Mathematically this line can be expressed by

$$FNR = 1 - \frac{c}{2} \tag{1}$$

in which FNR signifies the far-near-sky-vault ratio and c is the portion of the sky covered by thick clouds, expressed as a decimal.

It may be that the true relationship would be better expressed by a curve than by a straight line; for example, a curve similar to the dotted line for the October values in Figure 38. The coefficient of c can not be a fixed constant for all circumstances, as this quantity must depend in some way or other upon the proximity of the desks to the windows, or perhaps upon the ratio of window height to distance to the desks. For example, if the two desks in a room were equidistant or approximately equidistant from the windows the coefficient of c would necessarily be unity or approximately so. The value of the coefficient, 1/2, used in equation (1) is merely a good representation of the situation resulting from the particular physical factors existing in the building studied at Hagerstown.

Taking the problem as a whole, it is not alleged that the curve which really represents the true relationship is accurately known quantitatively. All that is alleged is that equation (1) represents the relationship for the building studied about as accurately as can be obtained from these observations.

APPLICATION OF FAR-NEAR-SKY-VAULT RATIO

The idea covered by equation (1) can also be expressed in another and perhaps more usable form:

$$Q_f = (1 - \frac{c}{2})\ Q_n \qquad (2)$$

in which Q_f is the sky-vault ratio expressed in foot-candles per square degree for the desks far from the windows and Q_n is the sky-vault ratio in foot-candles per square degree for the desks near the windows.

The significance of this line, equation (2), when interpreted in terms of the illumination of a room is that for each square degree of sky vault visible from a desk far from the windows there is on the average a certain amount of light supplied, depending upon the extent of cloudiness. If the sky be cloudless, a desk in the back of a room will receive as much light from each square degree of sky visible at this desk as a desk in the front of a room will receive from each square degree of sky visible from that desk. A square degree of sky vault is of equal value to a desk in the back of a room as it is to a desk at the front of a room if the sky be cloudless. On the other hand, if there be clouds in the sky, the square degrees are of unequal illuminating value. If there are clouds in the sky a square degree at the back of a room is of less value than a square degree at the front of the room. For example, if the sky be 70 per cent covered by thick clouds, according to the equation a square degree of sky visible at the back of a room supplies only 65 per cent as much light as a square degree visible at the front of a room.

A complete interpretation of this equation and the relationship upon which it is based requires that proper cognizance be taken of the pertinent details of the construction of the rooms in which the observations are made. In Table 1, column 8, there is given the distance of each of the desks from the window glass. The desks near the windows were approximately 60 inches from the glass and those in the back of the room about 260 inches. Probably of more direct bearing on this problem, however, are the ratios of these distances to the heights of the windows above the desks; these ratios are given in column 12 of the table. In the two first-floor rooms (Nos. 107 and 104) for the desks near the windows those ratios are about 0.6 and for the desks in the back of the room about 2.6. In the two rooms on the second floor the ratios are about 0.75 and 3.0, respectively.

These values probably have some direct bearing upon the problem, but their exact relationship to the problem is not evident. When they are compared with the graphs in section B of Figure 37 (section B is probably more nearly correct than section A because of the small

difference in time between the illumination and sky-vault measurements) it is seen that direction of exposure has more influence upon the far-near ratios than has the floor of the building with their accompanying small variations in height of windows and proximity of desks to windows. The graphs for the two rooms with a southeastern exposure (Nos. 107 and 207) lie considerably higher than the graphs for the other two rooms with a northwestern exposure (Nos. 104 and 204). This suggests that the southeastern sky may be brighter on the average throughout the day and year than is the northwestern sky, a plausible assertion.

Equations (1) and (2), and particularly (2), given on page 99, merit still further consideration. They may be used as a basis of generalization. By a proper expansion of equation (2) and a determination of the constants of the resulting equation, it probably will be found possible to forecast the illumination at any point in the working plane of a room for any kind of meteorological conditions. Furthermore, this may even be done from the plans of a building before the building is erected.

The data required for the application or use of equation (2) or its expansion are—

1. Sky-vault ratio expressed in foot-candles per square degree for any point, No. 1, in the room, preferably a point near the windows.

2. Sky vault expressed in square degrees which is visible at any other point, No. 2, in the room for which point it is desired to compute the illumination.

3. Degree of cloudiness existing at the time or to be assumed for use in the computation.

The sky-vault ratio in foot-candles per square degree at any point may be determined by measuring the illumination and the number of degrees of sky vault visible at that point, or it may be assumed.

Any assumed value of the sky-vault ratio would need to be based upon special standardizing observations taken for the purpose of determining this "constant" for all time. In assuming a value for any particular undertaking, it probably would be necessary to take a number of other factors into consideration, such as direction of exposure, hour of day, season of year, geographical latitude, the angle of elevation of the middle of the portion of sky visible at the point (No. 1), and the location of the two points within the room relative to the height of the windows. While this method of using assumed values of the sky-vault ratio will possibly be subject to larger error than would result in the case of the method of obtaining the value of the ratio by actual observation for each room, it nevertheless would be quite useful. It would give valuable average results, and would be the only one of the two alternatives which could be applied to the plans of a building before the building is erected.

Having selected or obtained by observation the desired value of the sky-vault ratio in foot-candles per square degree for the point in the room near the windows and the degree of cloudiness, there is computed by means of equation (2) the quantity Q_f, the sky-vault ratio for the point far from the windows. The next step is to compute the actual illumination from the equation.

$$I_{f(c)} = Q_f V_f \tag{3}$$

in which V_f is the observed sky vault visible at the point No. 2 far from the windows, and $I_{f(c)}$ is the computed illumination, I, at that point far from the windows.

An equation that probably is more convenient to use can be obtained by combining equations (2) and (3) giving

$$I_{f(c)} = V_f \left(1 - \frac{c}{2}\right) Q_n \tag{4}$$

This equation uses without modification and in simple form the three kinds of data stated on page 100 as necessary to compute the illumination at any point in a room in accordance with the relationship under consideration.

GENERALIZED FORMULA FOR ALL CONDITIONS

Equation (4) expresses a useful relationship but does not cover all possible conditions. It presupposes that there is some sky visible at each of the two desks. The formula fails or breaks down when there is no sky visible at the point far from the windows. It is easy to imagine a situation in which the sky is visible at a desk near the windows and is not visible at points in the same room far from the windows. Under these circumstances, equation (4) would indicate that there is no illumination at a point in the back of a room merely because no sky can be seen at that point. This, as everybody knows, is contrary to the fact. There are numerous occasions at which light in appreciable quantities is present with no visible sky.

It is necessary therefore to modify this equation to obtain a form which will be applicable to all conditions. The following expansion is derived from theoretical considerations alone. It has been done with a view of obtaining an equation which can be used under every possible set of circumstances. In order to decide whether this resulting equation is valid from the standpoint of engineering or not will require some actual observations.

If in equation (4) the equivalent $\frac{I_n}{V_n}$ be substituted for the sky-vault ratio Q_n, the equation becomes

$$I_{f(c)} = V_f \left(1 - \frac{c}{2}\right) \frac{I_n}{V_n} = \frac{V_f}{V_n} \left(1 - \frac{c}{2}\right) I_n \tag{5}$$

In this equation the quantities V_f and V_n refer to the area of the sky itself which is visible through the windows from each of the two desks. It is now proposed to substitute for each of these a new expression which will include everything which can be seen through the windows from each of the desks.

Suppose, for example, that from each of the desks there can be seen some sky, some trees, and a portion of a building. Each of these three objects is supplying some light to each of the two desks, the amount varying in accordance with the relative brightness of each object and the area (expressed in square degrees) of each object visible at each of the two desks. In other words, the total area visible through the windows from each of the desks whether the objects seen be sky, trees, or buildings, can be expressed as equivalent to a certain amount of clear sky so far as the ability of these objects to transmit light into the room is concerned. V_f can therefore be replaced by

$$(E_{sky}\ V_{sky} + E_{trees}\ V_{trees} + E_{building}\ V_{building})_f$$

in which E_{trees} represents the emissivity or relative ability of the trees to transmit light into the room as compared with the ability of cloudless sky, and V_{trees} represents the visible area of the trees expressed in square degrees. This generalized expression for V_f can be more briefly stated in the form given by the following equation:

$$(6) \qquad V_f = (E_{sky}\ V_{sky} + E_{trees}\ V_{trees} + E_{building}\ V_{building})_f = (\Sigma EV)_f$$

In this equation $(\Sigma EV)_f$ signifies the summation of all similar products of the type EV for each kind of object visible through the windows at the desks far from the windows. In like manner, V_n can be replaced by a similar expression $(\Sigma EV)_n$ and be understood to signify the summation of all EV products for objects visible through the windows at the desk near the windows.

When these expressions are substituted into equation (5) the expression $\left(1-\frac{c}{2}\right)$ is probably destroyed; i. e., the relationship connecting the influence of clouds, distance to the desks, and height of windows, is no longer expressed by the factor $\left(1-\frac{c}{2}\right)$. The correct new relationship will need to be determined. For this reason, in the new general formula the relationship is merely expressed in general terms as some function or relation of extent of cloudiness, distance to desks, and height of windows (c, d, and h), as follows, "*function*, (c, d, h)."

When these indicated substitutions are made, equation (5) becomes—

$$(7) \qquad I_{f(c)} = \frac{(\Sigma EV)_f}{(\Sigma EV)_n} \cdot function\ (c, d, h) \cdot I_n$$

$$(8) \qquad = (\Sigma EV)_f \cdot function\ (c, d, h) \cdot \frac{I_n}{(\Sigma EV)_n}$$

Equation (8) can be expressed in the form—

$$(9) \qquad I_{f(c)} = (\Sigma EV)_f \cdot \textit{function}\ (c, d, h) \cdot Q'_n$$

in which Q'_n is a modified sky-vault ratio obtained by dividing I_n, the illumination at the near desk by the equivalent sky vault for that desk, this latter quantity being an equivalent measure of the light giving power of all objects visible through the windows at the near desk in terms of cloudless sky. It is to be noticed that equation (9) is quite similar to equation (4), which is based upon visible sky vault only.

Equation (9) is offered as a generalized formula for computing the illumination at any point in a room under any circumstances. For its use, in addition to the three kinds of data necessary to be known for this kind of a task, as stated on page 100, there must also be known the apparent size in square degrees of each object visible through the windows, and its relative emissivity or brightness (in that direction) in terms of a cloudless sky. The exact form of the function of c, d, and h must also be determined; this, however, is a fixed relationship. After it has once been determined, it should be applicable to all rooms alike.

SUMMARY

The following conclusions have been indicated by the analysis of the data included in this paper:

1. As a larger portion of the sky becomes covered by thick clouds, the outside illumination decreases while the sky brightness increases.

2. The influence of clouds upon indoor illumination is well marked and depends largely upon the direction of the exposure of the room and the time of day.

3. There is, in general, a small increase in the illumination in a room as the extent of cloudiness increases, for either thick or thin varieties, until about half of the sky is covered. Beyond this point, i. e., when the clouds increase and cover more than half of the sky, there is little change in the indoor illumination if the clouds be of thin varieties, but if the clouds be of thick varieties a material reduction in the inside illumination results.

4. Of the illumination prevailing with a cloudless sky, 80 per cent or more, on an average, is still obtained until in excess of eight-tenths of the sky is covered by thick clouds.

5. The inside-outside illumination ratio is not constant, but varies with the season of the year, the hour of the day, and the condition of cloudiness.

6. The ratio between the inside illumination and the sky brightness also varies with the season, the hour, and the condition of cloudiness, but possibly to a lesser extent than the illumination ratio.

7. As the percentage of the sky overcast with (thick) clouds increases, the inside illumination decreases (neglecting the small increase for the smaller classes as mentioned in No. 3 of summary), the illumination ratio increases, and the sky brightness ratio decreases.

8. The ratio expressing the influence of ten-tenths clouds upon the illumination as compared with that of zero clouds, i. e., the average illumination for ten-tenths clouds divided by that for zero clouds, is not constant. It varies according to the season, the hour of day and direction of exposure, and the distance to the windows. In other words the effect of clouds varies with the season, hour, direction of exposure, and distance to the windows.

9. The distribution coefficient, or ratio of the illumination for desks near the windows to that for desks similarly situated but far from the windows, varies according to the season, the hour of the day, and the extent of cloudiness.

10. The uniformity coefficient, or ratio of the maximum illumination to the minimum illumination in a room varies according to the season, the hour of the day, and the extent of cloudiness.

11. A fairly accurate estimate of the uniformity coefficient of a room is given by the ratio of the maximum and minimum values of the sky vault visible at the working plane.

12. The illumination in foot-candles received from each square degree of sky vault visible at any desk may be constant, i. e., the foot-candles per square degree may be the same for all points in the working plane without reference as to whether they are near the windows or the direction of exposure.

13. The far-near-sky-vault ratio, or ratio of the foot-candles per square degree for a desk near the windows to that for a desk away from the windows, appears to be independent of the hour of the day and the season, but varies according to the extent of cloudiness. For zero clouds, the ratio has a value of or near unity, but for ten-tenths, (thick), clouds its value is only about half of this amount.

14. The far-near-sky-vault ratio can be utilized to compute or forecast the illumination at any point in the working plane of a room, especially if the illumination at any one point in the room be known.

15. A generalized formula based upon the far-near-sky-vault ratio is suggested, by the use of which it is believed that it will be possible to compute or forecast the illumination at any point in a room for any combination of environmental obstructions even though no sky be visible at the chosen point in the working plane.

APPENDIX

TABLE A.—*Monthly mean values of the illumination for each of 24 selected school desks, arranged for each month and class of clouds, Hagerstown, Md., as derived from 7 mean hourly values for each month, September 17, 1923, to April 15, 1924*

ROOM NO. 107

Clouds	Mean illumination in foot candles							
	All months	Oct.[1]	Nov.[1]	Dec.[1]	Jan.[1]	Feb.[1]	Mar.[1]	Apr.[1]
DESK NO. 1.—SOUTHEAST EXPOSURE								
0	162.9	172.0	164.4	130.3	118.9	200.2	199.8	155.0
2	168.0	162.4	204.7	151.9	121.5	152.3	179.6	203.4
5	197.8	182.7	173.4	146.9	162.0	245.5	258.6	215.3
8	176.0	224.2	146.5	111.2	167.4	220.1	241.9	120.7
10	99.1	130.2	65.4	64.2	65.0	129.7	123.2	116.3
A	173.2	195.0	168.0	130.5	116.7	176.7	207.1	218.1
B	221.3	210.5	339.3	167.3	74.9	334.0	216.7	206.1
C	195.4	----------	161.8	215.9	154.0	160.3	249.9	230.8
DESK NO. 2.—SOUTHEAST EXPOSURE								
0	177.7	184.2	179.6	142.8	127.3	218.3	223.6	169.8
2	181.1	164.4	219.8	159.4	134.6	173.9	191.5	224.0
5	213.3	195.7	192.6	187.1	173.3	250.2	274.2	220.3
8	178.2	251.7	145.8	111.2	173.0	211.0	235.5	119.2
10	98.6	124.5	63.0	62.9	64.2	140.4	120.8	114.4
A	183.9	198.0	179.4	144.9	128.2	192.9	223.9	219.9
B	248.3	252.2	362.7	161.9	76.3	322.2	329.4	233.7
C	201.4	----------	156.1	225.0	156.9	164.2	268.6	237.7
DESK NO. 3.—SOUTHEAST EXPOSURE								
0	157.7	157.8	156.9	134.3	121.1	200.3	198.4	135.2
2	157.3	148.1	197.6	134.4	128.5	155.1	163.7	173.5
5	176.4	168.7	154.4	160.4	150.3	200.5	234.0	166.3
8	142.0	203.6	105.8	87.4	149.2	171.8	184.7	91.6
10	73.1	93.6	42.7	53.3	49.4	99.3	86.4	87.0
A	167.8	174.1	156.2	136.5	128.1	178.3	198.1	203.2
B	219.2	224.0	329.0	155.5	65.9	333.8	221.7	204.3
C	167.9	----------	125.5	207.2	150.2	132.2	210.5	181.6
DESK NO. 4.—SOUTHEAST EXPOSURE								
0	18.0	11.9	17.1	20.1	20.9	24.0	20.1	11.8
2	17.2	9.6	18.5	16.7	22.2	20.0	17.0	16.6
5	14.0	9.5	13.1	14.4	13.2	17.2	18.0	12.4
8	10.0	8.7	8.1	6.7	11.7	13.3	14.5	6.8
10	5.3	4.9	3.1	4.5	3.7	7.4	7.8	6.0
A	18.7	12.7	17.4	19.0	24.9	21.9	21.7	13.5
B	18.6	14.0	34.5	14.2	6.6	25.0	21.4	14.4
C	13.8	----------	10.2	25.7	9.6	9.7	16.3	11.2
DESK NO. 5.—SOUTHEAST EXPOSURE								
0	21.0	14.2	19.6	21.9	22.0	30.3	23.8	15.0
2	20.3	11.8	21.4	20.2	22.7	24.4	20.5	21.2
5	17.3	11.4	15.3	16.1	17.1	21.4	23.6	16.2
8	12.2	10.7	9.8	8.3	13.4	17.2	17.4	8.8
10	6.9	6.0	4.2	5.4	4.6	9.5	10.2	8.2
A	21.2	14.6	19.8	21.8	25.3	24.4	25.4	17.0
B	22.7	15.8	39.0	15.7	8.2	34.4	26.2	19.4
C	16.5	----------	11.0	28.1	10.9	12.5	21.3	15.3
DESK NO. 6—SOUTHEAST EXPOSURE.								
0	17.0	12.4	16.7	16.3	14.7	23.8	21.3	13.6
2	15.9	10.1	17.9	12.9	15.2	18.2	18.7	18.2
5	14.3	9.4	12.5	13.6	14.6	17.2	17.8	15.1
8	10.6	8.7	7.7	7.4	11.0	14.6	16.4	8.3
10	6.5	5.0	3.6	4.8	4.1	8.4	9.9	9.7
A	16.4	12.3	15.9	15.0	15.8	18.2	22.2	15.2
B	18.6	13.7	29.0	12.8	7.2	26.9	23.3	17.5
C	14.5	----------	10.8	21.4	10.1	11.6	19.2	14.0

[1] Interval ending on the 15th day of the indicated month.

TABLE A.—*Monthly mean values of the illumination for each of 24 selected school desks, arranged for each month and class of clouds, Hagerstown, Md., as derived from 7 mean hourly values for each month, September 17, 1923, to April 15, 1924*—Continued

ROOM NO. 104

Clouds	Mean illumination in foot candles							
	All months	Oct.[1]	Nov.[1]	Dec.[1]	Jan.[1]	Feb.[1]	Mar.[1]	Apr.[1]
DESK NO. 7.—NORTHWEST EXPOSURE								
0	11.9	11.4	10.5	9.3	8.4	15.6	16.9	11.0
2	12.2	13.8	9.6	9.3	9.9	12.1	14.1	16.3
5	13.5	12.4	11.2	10.1	9.2	14.0	21.8	16.1
8	11.0	10.9	6.5	8.1	7.8	13.5	18.9	11.0
10	6.9	7.6	4.2	4.5	4.0	8.6	11.1	8.6
A	11.6	12.4	10.6	9.3	9.1	9.7	16.2	13.9
B	14.1	14.8	10.1	12.0	9.1	15.3	19.5	17.6
C	12.8	----------	10.3	11.6	8.2	13.9	18.7	13.8
DESK NO. 8.—NORTHWEST EXPOSURE								
0	12.3	11.1	11.1	9.8	8.9	15.9	17.1	12.2
2	12.1	13.5	9.9	9.2	10.6	12.6	12.9	16.1
5	14.1	12.0	11.7	10.4	9.6	14.2	23.9	16.6
8	11.4	10.6	7.0	8.8	8.3	14.0	20.0	10.9
10	7.4	7.8	4.5	4.8	4.3	9.1	12.2	9.4
A	11.7	11.7	10.5	9.7	9.4	10.0	16.8	14.0
B	14.4	14.4	10.5	12.3	9.0	15.9	20.6	18.0
C	13.4	----------	10.3	12.4	8.1	14.0	20.2	15.1
DESK NO. 9.—NORTHWEST EXPOSURE								
0	9.3	7.9	8.2	7.7	7.2	12.3	12.3	9.2
2	9.0	8.6	7.6	7.7	8.4	9.4	10.5	11.1
5	10.4	7.9	8.7	7.8	8.5	10.6	17.6	11.7
8	8.2	6.5	4.8	6.5	6.7	10.5	14.4	7.9
10	5.5	4.9	3.1	3.6	3.5	6.8	9.6	7.0
A	8.7	8.3	7.5	7.4	7.8	7.2	12.9	10.1
B	10.3	9.4	8.2	9.1	6.7	10.5	15.2	12.7
C	9.8	----------	7.3	9.2	7.6	9.1	15.1	10.8
DESK NO. 10.—NORTHWEST EXPOSURE								
0	37.1	33.0	31.7	29.1	28.4	48.9	53.4	35.5
2	38.0	46.1	30.0	29.0	33.7	39.8	43.8	43.8
5	55.2	55.0	43.4	44.0	37.8	56.1	87.8	62.2
8	62.0	63.2	42.9	50.2	47.3	75.9	87.3	67.4
10	47.2	53.8	32.3	33.0	31.4	62.5	65.2	52.0
A	36.9	37.6	30.5	28.3	31.6	39.7	49.1	41.6
B	54.0	54.7	37.5	50.1	34.5	53.6	74.1	73.5
C	66.9	----------	55.8	57.5	37.8	78.1	93.8	78.3
DESK NO. 11.—NORTHWEST EXPOSURE								
0	72.0	73.2	61.2	50.0	50.7	87.9	103.0	78.0
2	78.1	107.3	60.4	54.5	58.3	81.0	85.9	99.3
5	101.1	115.3	90.0	79.3	62.1	94.2	147.2	119.9
8	108.1	117.8	72.9	85.7	79.6	126.8	152.1	121.6
10	75.8	93.0	53.5	50.9	49.1	98.1	102.5	83.2
A	73.5	91.8	62.0	49.6	56.0	76.2	89.5	89.2
B	101.3	101.9	67.6	90.5	65.0	94.4	134.0	155.7
C	121.6	----------	104.1	94.3	64.7	147.7	162.3	156.7
DESK NO. 12.—NORTHWEST EXPOSURE								
0	78.2	82.4	69.3	52.7	52.5	92.9	109.1	88.5
2	85.8	117.7	63.1	57.2	61.2	88.4	99.6	113.7
5	107.5	126.7	95.9	82.8	70.5	101.4	149.8	125.6
8	109.7	114.4	71.6	90.6	79.5	131.9	156.1	124.1
10	75.4	88.9	55.2	50.7	49.8	99.0	101.9	82.6
A	78.4	97.2	67.1	53.8	55.3	79.7	100.5	94.9
B	107.7	112.0	69.8	94.0	73.6	97.3	145.6	161.9
C	125.1	----------	110.4	99.6	72.1	147.5	169.9	151.1

[1] Interval ending on the 15th day of the indicated month.

TABLE A.—*Monthly mean values of the illumination for each of 24 selected school desks, arranged for each month and class of clouds, Hagerstown, Md., as derived from 7 mean hourly values for each month, September 17, 1923, to April 15, 1924*—Continued

ROOM No. 204

Clouds	Mean illumination in foot candles							
	All months	Oct.[1]	Nov.[1]	Dec.[1]	Jan.[1]	Feb.[1]	Mar.[1]	Apr.[1]
DESK No. 13.—NORTHWEST EXPOSURE								
0	9.7	8.7	8.6	8.2	7.3	12.7	12.4	9.8
2	9.8	10.6	8.2	8.3	8.5	9.2	10.8	12.7
5	10.7	9.8	10.1	8.5	7.8	10.8	15.4	12.4
8	7.6	7.1	4.9	6.3	6.1	9.1	12.2	7.4
10	4.8	5.5	3.0	3.3	2.9	5.9	7.6	5.7
A	9.4	8.9	8.5	8.4	7.8	8.0	13.4	10.5
B	10.4	10.6	8.5	10.1	7.6	8.7	14.0	13.2
C	9.8	---	8.7	9.3	7.0	9.4	13.5	10.7
DESK No. 14.—NORTHWEST EXPOSURE								
0	9.6	7.9	8.3	8.5	7.5	13.2	12.2	9.7
2	9.5	9.0	8.2	8.0	8.8	9.1	10.9	12.9
5	10.8	8.4	9.0	8.1	8.2	11.5	17.7	12.6
8	7.9	6.7	4.9	6.3	6.5	10.0	13.0	7.7
10	5.1	5.3	3.0	3.5	3.2	6.2	8.3	6.0
A	9.1	8.2	7.9	8.4	7.8	7.8	13.4	10.4
B	10.8	9.9	7.9	10.1	7.4	13.2	14.3	12.7
C	10.0	---	8.0	9.4	7.7	9.3	15.1	10.6
DESK No. 15.—NORTHWEST EXPOSURE								
0	6.4	4.5	5.3	6.2	5.3	9.0	8.0	6.4
2	6.1	4.9	5.4	5.5	6.0	6.1	7.2	7.7
5	7.0	4.6	5.9	5.3	5.7	7.7	12.0	7.7
8	4.9	3.5	2.8	4.2	4.4	6.9	8.2	4.6
10	3.2	2.9	1.7	2.2	2.1	4.2	5.5	3.9
A	5.9	4.6	4.8	5.7	5.8	4.9	9.0	6.5
B	6.8	5.3	5.8	6.3	4.8	8.9	8.7	8.1
C	6.2	---	4.5	6.0	4.6	6.2	9.3	6.9
DESK No. 16.—NORTHWEST EXPOSURE								
0	25.9	21.3	20.8	21.6	20.7	35.7	37.0	24.2
2	27.3	30.7	21.5	22.4	23.5	28.5	33.1	31.6
5	40.7	43.0	29.1	29.4	26.1	47.6	67.2	42.4
8	41.1	40.1	29.8	33.2	30.6	51.3	58.0	44.8
10	32.3	40.4	21.8	22.6	21.2	41.3	44.9	33.8
A	24.2	25.5	21.2	21.3	22.0	26.7	36.8	15.8
B	36.8	35.1	26.1	35.8	24.0	37.3	52.6	46.4
C	45.6	---	35.3	39.8	27.6	53.3	74.7	43.0
DESK No. 17.—NORTHWEST EXPOSURE								
0	68.6	71.2	56.7	46.7	48.1	82.6	99.7	75.4
2	75.0	104.2	58.1	51.2	53.9	74.6	82.4	100.6
5	102.8	116.5	99.1	74.4	57.4	119.3	142.2	110.4
8	95.7	107.0	66.9	75.5	67.7	114.1	132.4	106.1
10	69.6	95.0	48.9	46.6	43.6	88.3	91.1	73.8
A	70.8	86.0	57.9	48.4	51.9	72.9	90.3	88.1
B	91.1	98.9	59.1	80.9	61.7	86.1	126.1	125.2
C	112.9	---	92.4	91.6	68.3	146.6	147.8	130.7
DESK No. 18.—NORTHWEST EXPOSURE								
0	62.1	64.2	53.5	41.4	41.8	74.5	87.6	71.7
2	68.1	90.2	52.1	45.5	46.9	68.4	78.4	94.9
5	87.1	97.1	86.7	65.1	47.8	99.4	114.1	99.5
8	79.0	84.6	56.6	61.3	55.4	93.7	110.3	90.9
10	55.8	73.7	37.9	37.2	35.7	72.3	72.1	61.8
A	62.8	77.0	55.0	41.9	43.2	63.9	84.5	74.1
B	80.6	85.5	48.6	69.5	56.0	71.9	111.2	121.4
C	95.5	---	81.0	75.2	56.8	117.7	128.1	114.2

[1] Interval ending on the 15th day of the indicated month.

TABLE A.—*Monthly mean values of the illumination for each of 24 selected school desks, arranged for each month and class of clouds, Hagerstown, Md., as derived from 7 mean hourly values for each month, September 17, 1923, to April 15, 1924*—Continued

ROOM NO. 207

Clouds	Mean illumination in foot candles							
	All months	Oct.[1]	Nov.[1]	Dec.[1]	Jan.[1]	Feb.[1]	Mar.[1]	Apr.[1]
DESK NO. 19.—SOUTHEAST EXPOSURE								
0	14.8	11.5	14.0	14.7	13.2	20.8	17.4	12.2
2	14.2	10.6	15.0	12.5	14.4	14.2	16.1	16.7
5	14.2	13.5	11.6	10.9	13.2	15.7	20.8	13.8
8	10.3	10.6	9.1	6.5	10.3	12.4	15.7	7.6
10	6.1	7.1	3.8	4.3	3.9	7.4	8.6	7.6
A	14.5	13.0	13.6	13.3	14.6	14.4	19.8	12.5
B	15.7	16.0	16.2	15.0	7.6	22.1	17.7	15.0
C	12.7	----------	11.5	16.5	7.8	10.8	16.4	13.0
DESK NO. 20.—SOUTHEAST EXPOSURE								
0	20.4	15.3	19.2	18.1	19.8	31.4	23.5	15.3
2	20.5	14.5	21.7	17.3	22.7	25.3	21.6	20.5
5	18.3	18.2	14.0	14.2	17.1	20.2	26.8	17.6
8	13.7	13.5	11.5	9.2	14.8	17.4	20.7	9.0
10	7.4	8.8	4.5	5.4	4.7	9.3	10.2	9.2
A	20.6	18.0	18.9	19.1	22.4	22.4	26.9	16.8
B	25.7	22.1	22.7	22.3	9.2	34.9	22.4	18.6
C	16.8	----------	14.8	23.9	11.2	12.9	21.2	16.6
DESK NO. 21.—SOUTHEAST EXPOSURE								
0	19.2	13.7	18.1	18.8	21.1	29.8	20.6	12.2
2	19.2	13.3	20.3	18.3	22.4	27.4	16.2	16.6
5	15.9	14.6	14.4	13.8	15.9	18.0	21.6	12.7
8	11.6	11.4	9.4	7.8	14.2	15.2	15.9	7.2
10	5.8	7.1	3.5	4.4	3.8	7.1	7.6	7.0
A	19.6	16.4	18.0	18.9	23.5	22.8	24.3	13.0
B	19.7	19.0	22.8	23.1	7.6	32.3	18.7	14.7
C	14.6	----------	13.2	25.4	10.2	9.0	16.6	13.1
DESK NO. 22.—SOUTHEAST EXPOSURE								
0	122.4	114.6	123.2	103.7	106.2	181.6	147.7	79.9
2	130.3	118.6	152.7	125.2	114.9	137.1	155.5	108.4
5	148.3	130.8	148.5	115.3	153.5	171.8	206.3	112.1
8	108.2	112.5	97.5	63.9	122.8	138.2	167.8	55.0
10	52.4	65.4	33.2	39.9	35.2	72.2	60.5	60.3
A	127.9	148.0	130.1	105.2	116.4	147.7	158.7	89.5
B	160.1	162.1	190.7	150.4	48.7	301.0	155.4	112.7
C	132.3	----------	134.2	177.5	116.0	84.4	168.0	113.8
DESK NO. 23.—SOUTHEAST EXPOSURE								
0	148.2	142.4	147.9	120.1	117.8	205.6	186.0	117.9
2	157.3	149.2	183.2	142.1	127.8	164.8	177.9	156.4
5	187.4	204.6	160.4	143.1	156.2	228.9	237.3	181.4
8	155.3	173.1	137.8	91.4	149.1	192.9	221.9	120.9
10	87.4	114.8	60.3	59.7	58.0	111.6	105.2	102.1
A	159.1	187.7	162.1	122.7	119.5	174.3	198.0	149.7
B	200.4	217.2	239.7	179.4	64.1	293.5	215.2	193.8
C	172.1	----------	184.4	204.2	123.4	108.8	242.5	169.4
DESK NO. 24.—SOUTHEAST EXPOSURE								
0	107.6	110.0	101.4	78.8	78.3	141.5	141.8	101.3
2	109.2	99.6	123.0	86.5	82.6	111.4	130.5	131.1
5	137.6	156.9	92.6	90.0	93.7	195.5	183.5	150.8
8	113.9	131.7	98.9	71.9	105.0	142.3	159.0	88.1
10	70.8	92.7	49.5	47.0	46.8	91.1	86.4	82.1
A	108.8	137.2	87.6	80.9	78.2	117.8	145.2	114.8
B	145.9	172.0	129.3	117.7	44.6	214.3	183.4	159.7
C	123.8	----------	124.6	138.2	82.0	90.2	180.4	127.1

[1] Interval ending on the 15th day of the indicated month.

TABLE B.—*Hourly mean values of the illumination for each of 24 selected school desks, arranged for each hour and class of clouds, Hagerstown, Md., as derived from 7 mean monthly values for each hour, September 17, 1923, to April 15, 1924*

ROOM NO. 107

Clouds	Mean illumination in foot candles							
	All hours	9.40	10.40	11.40	12.40	1.40	2.40	3.40
DESK NO. 1.—SOUTHEAST EXPOSURE								
0	162.9	293.0	292.1	224.5	145.2	87.4	57.3	41.1
2	163.8	268.5	286.0	225.4	160.0	98.0	61.0	47.9
5	204.7	273.1	378.2	323.0	175.5	132.2	87.4	63.8
8	175.3	181.3	308.9	254.2	197.4	110.7	114.6	59.7
10	99.2	101.1	126.1	126.8	124.1	96.3	70.3	49.4
A	173.2	304.1	304.2	248.4	145.3	106.9	58.6	44.7
B	224.6	412.7	403.3	302.6	180.2	116.1	94.7	62.9
C	214.4	295.0	389.0	265.2	166.3	169.3	144.9	71.3
DESK NO. 2.—SOUTHEAST EXPOSURE								
0	177.7	303.6	322.0	261.3	165.3	90.1	59.7	41.6
2	183.5	295.8	332.4	261.4	176.9	103.6	66.2	48.1
5	215.2	286.8	378.9	340.0	196.8	149.6	91.3	63.2
8	179.8	190.1	320.4	252.8	203.3	121.5	112.4	58.2
10	96.9	97.8	120.2	124.3	122.5	95.9	68.9	48.5
A	183.9	301.9	325.9	275.1	171.9	105.5	61.6	45.5
B	237.3	409.1	437.4	350.1	196.5	117.8	88.3	62.2
C	213.5	284.7	346.9	285.1	182.0	181.3	144.4	70.1
DESK NO. 3.—SOUTHEAST EXPOSURE								
0	157.7	280.2	288.1	234.8	147.7	75.9	45.1	32.2
2	159.1	255.6	299.4	234.9	154.5	83.6	49.2	36.8
5	177.2	208.1	335.9	290.3	165.2	120.8	72.2	47.8
8	151.2	143.7	327.8	202.5	166.7	90.7	83.6	43.4
10	73.1	80.6	95.1	91.5	91.9	68.8	49.7	34.1
A	167.8	296.4	293.3	260.6	149.6	93.7	47.9	33.2
B	208.4	363.4	385.8	325.0	165.7	99.9	71.4	47.3
C	183.0	250.8	338.4	243.6	155.7	138.5	103.2	50.7
DESK NO. 4.—SOUTHEAST EXPOSURE								
0	18.0	46.4	26.5	20.1	13.6	8.9	6.2	4.2
2	17.9	50.5	23.7	17.7	13.7	9.0	5.7	4.8
5	13.9	17.6	24.9	20.0	13.9	10.2	6.6	3.8
8	10.0	11.2	16.9	12.8	11.6	7.5	6.0	3.9
10	5.4	7.0	6.6	6.4	6.7	4.9	3.6	2.3
A	18.7	48.0	30.6	20.2	13.2	8.4	6.1	4.5
B	17.6	34.1	31.7	20.6	14.5	10.0	7.0	5.1
C	16.3	36.5	21.8	16.4	13.7	11.5	9.4	4.8
DESK NO. 5.—SOUTHEAST EXPOSURE								
0	21.0	52.1	32.2	22.7	16.0	10.7	7.6	5.4
2	21.0	56.5	27.8	21.2	16.1	11.5	7.6	6.2
5	17.3	24.7	29.0	23.7	17.4	13.1	8.2	5.2
8	12.3	14.7	19.7	15.8	13.9	9.1	7.5	5.3
10	6.9	8.5	8.7	8.3	8.4	6.4	4.7	3.2
A	21.2	54.1	31.2	23.7	15.4	10.5	7.5	5.8
B	20.8	39.3	37.0	24.2	17.1	12.0	9.3	6.9
C	19.9	40.4	26.7	21.3	16.9	15.2	12.8	6.3
DESK NO. 6.—SOUTHEAST EXPOSURE								
0	17.5	37.2	26.0	19.0	13.9	14.1	7.4	5.2
2	16.3	37.5	22.1	18.1	13.6	9.9	7.1	5.8
5	14.7	21.9	21.2	20.5	15.2	12.0	7.5	4.8
8	10.6	11.6	14.9	14.2	12.5	8.6	7.0	5.1
10	6.5	7.1	7.9	7.7	9.5	6.0	4.5	2.8
A	16.3	36.4	24.5	18.4	13.1	9.7	7.0	5.3
B	17.4	30.8	29.9	20.1	15.0	10.8	8.8	6.3
C	16.5	26.7	25.7	16.7	15.2	13.7	11.8	5.9

TABLE B.—*Hourly mean values of the illumination for each of 24 selected school desks, arranged for each hour and class of clouds, Hagerstown, Md., as derived from 7 mean monthly values for each hour, September 17, 1923, to April 15, 1924*—Continued

ROOM NO. 104

Clouds	Mean illumination in foot candles							
	All hours	9.40	10.40	11.40	12.40	1.40	2.40	3.40
DESK NO. 7.—NORTHWEST EXPOSURE								
0	12.0	8.8	10.5	11.4	13.1	12.9	13.3	14.2
2	12.2	9.4	9.8	10.3	11.6	13.6	14.2	16.3
5	13.7	11.1	14.7	14.7	14.3	15.1	13.4	12.8
8	11.0	7.2	10.2	12.2	14.3	11.5	10.9	10.8
10	6.9	5.6	7.5	8.9	9.1	7.3	6.2	4.0
A	11.6	8.6	9.8	10.5	11.5	11.9	12.7	16.0
B	14.7	10.7	15.3	14.5	15.7	14.3	16.2	15.9
C	13.5	10.0	12.9	11.8	15.5	17.8	17.4	9.2
DESK NO. 8—NORTHWEST EXPOSURE								
0	12.1	7.9	11.3	12.1	13.8	13.1	12.8	13.4
2	12.3	9.8	10.6	10.6	12.5	13.4	14.2	14.8
5	14.0	11.6	16.3	15.0	15.7	15.4	13.7	10.2
8	11.4	7.6	11.1	12.8	15.5	11.7	11.2	9.9
10	7.5	6.4	8.1	9.5	9.9	7.8	6.5	4.1
A	11.7	9.2	10.2	11.4	12.3	11.9	12.2	14.8
B	14.9	10.8	16.5	14.8	16.9	14.6	15.7	15.2
C	14.2	11.0	13.9	12.7	16.3	18.6	18.0	9.2
DESK NO. 9—NORTHWEST EXPOSURE								
0	9.3	7.3	9.0	10.1	10.7	10.0	9.2	8.5
2	9.0	7.7	8.6	8.8	9.5	10.0	9.9	8.8
5	10.3	8.7	12.0	12.3	12.0	11.0	9.3	6.8
8	8.2	5.7	8.5	10.0	10.9	8.4	7.6	6.2
10	5.5	4.7	6.1	7.2	7.2	5.7	4.6	2.9
A	8.7	7.2	8.1	9.5	9.7	8.8	8.5	9.0
B	10.4	8.2	12.8	10.9	9.7	10.2	11.1	9.7
C	10.4	8.4	10.8	10.7	11.5	12.7	12.6	6.4
DESK NO. 10.—NORTHWEST EXPOSURE								
0	37.2	26.7	31.2	36.6	39.9	42.9	42.7	40.1
2	37.9	28.6	31.4	31.2	37.3	42.8	46.4	47.3
5	56.0	47.5	61.1	63.7	54.4	66.3	53.0	46.0
8	60.9	47.4	62.2	69.2	75.8	69.0	62.0	40.9
10	47.2	39.5	51.6	62.4	58.5	50.6	40.7	26.9
A	36.9	29.7	32.1	33.7	38.1	39.1	41.2	44.5
B	56.5	45.0	59.0	53.8	64.9	53.8	69.7	49.3
C	69.5	47.9	71.1	69.9	63.1	90.2	94.7	49.6
DESK NO. 11.—NORTHWEST EXPOSURE								
0	72.1	41.0	48.2	57.4	68.5	83.0	95.0	111.4
2	77.6	45.1	52.7	51.2	72.5	84.3	108.3	129.4
5	103.5	72.0	91.5	98.0	95.0	128.2	116.2	123.5
8	107.9	70.3	93.8	117.8	131.3	120.5	119.5	102.0
10	75.8	62.2	81.4	96.3	97.0	81.8	67.0	44.7
A	73.4	45.5	51.1	56.2	67.9	81.2	89.4	122.8
B	107.4	76.9	92.1	90.8	109.6	107.8	137.9	136.8
C	125.0	80.8	110.3	108.4	115.8	166.7	189.4	103.8
DESK NO. 12.—NORTHWEST EXPOSURE								
0	78.2	41.5	48.3	58.7	69.3	84.8	104.6	140.2
2	85.5	45.0	51.3	55.3	75.5	94.0	120.4	157.1
5	110.2	74.0	91.6	98.2	99.7	129.5	136.3	142.0
8	109.7	70.8	95.2	119.8	131.8	120.4	123.6	106.2
10	75.5	61.0	81.6	94.2	98.9	80.2	67.8	44.5
A	78.3	45.9	51.6	57.5	70.7	88.0	97.4	137.3
B	114.8	77.3	93.6	97.8	113.8	112.5	151.2	157.1
C	128.3	77.9	111.4	114.7	120.4	166.6	194.4	113.0

TABLE B.—*Hourly mean values of the illumination for each of 24 selected school desks, arranged for each hour and class of clouds, Hagerstown, Md., as derived from 7 mean monthly values for each hour, September 17, 1923, to April 15, 1924*—Continued

ROOM NO. 204

Clouds	Mean illumination in foot candles							
	All hours	9.40	10.40	11.40	12.40	1.40	2.40	3.40
DESK NO. 13.—NORTHWEST EXPOSURE								
0	9.9	7.6	9.2	10.4	10.4	9.3	10.1	12.2
2	9.8	8.5	8.0	8.1	9.8	9.5	11.0	13.8
5	10.8	9.5	11.1	10.4	11.8	11.3	11.6	9.9
8	7.6	5.0	8.1	8.7	10.7	7.2	7.0	6.6
10	4.9	4.1	5.3	6.1	6.8	5.0	4.1	2.7
A	9.4	7.1	8.3	8.9	9.2	9.4	10.1	12.7
B	11.3	9.0	11.0	10.3	13.0	9.9	12.6	13.1
C	10.5	8.6	10.1	8.9	13.1	11.9	13.4	7.4
DESK NO. 14.—NORTHWEST EXPOSURE								
0	9.6	8.2	10.3	9.7	10.7	9.2	9.2	10.2
2	9.6	9.0	9.0	8.7	9.7	8.9	9.9	12.0
5	10.9	9.9	13.0	11.7	12.1	11.2	10.5	7.6
8	7.9	5.4	8.7	9.4	10.8	7.6	6.8	6.3
10	5.1	4.4	5.6	6.3	7.0	5.2	4.2	2.7
A	9.1	7.7	8.8	9.4	9.6	8.7	9.0	10.7
B	11.1	9.6	11.8	10.7	13.3	9.9	11.4	11.0
C	10.1	8.7	10.9	10.5	12.8	12.2	8.4	7.0
DESK NO. 15.—NORTHWEST EXPOSURE								
0	6.4	5.9	7.4	7.2	7.3	6.1	5.5	5.4
2	6.2	6.3	6.6	6.4	6.3	6.0	5.6	5.9
5	7.0	6.5	8.8	8.1	8.2	7.3	5.9	3.9
8	4.9	3.6	5.8	6.0	6.8	4.7	4.1	3.3
10	3.2	2.8	3.6	4.0	4.3	3.4	2.4	1.8
A	5.9	5.4	6.3	6.8	6.6	5.5	5.3	5.5
B	7.0	6.3	8.2	6.9	8.6	6.2	7.0	5.7
C	6.6	5.5	7.2	6.5	7.7	7.8	7.6	4.2
DESK NO. 16.—NORTHWEST EXPOSURE								
0	25.9	20.5	24.3	27.0	28.7	28.8	26.4	25.7
2	27.3	22.2	23.8	25.2	27.1	30.1	29.0	33.7
5	41.6	37.4	50.2	46.6	42.1	45.5	39.6	29.6
8	41.0	33.8	44.0	47.6	49.5	41.5	40.5	30.0
10	32.3	27.8	35.7	41.4	41.3	34.9	27.2	17.5
A	27.0	29.6	24.1	25.7	27.2	26.8	26.8	29.0
B	38.3	34.2	39.6	36.5	45.4	35.9	42.6	33.8
C	47.8	32.8	50.4	48.6	45.1	64.7	60.8	32.4
DESK NO. 17.—NORTHWEST EXPOSURE								
0	68.7	39.6	47.1	56.2	64.9	74.0	85.9	113.5
2	74.6	44.0	46.9	51.1	69.5	82.1	99.9	129.0
5	104.4	73.1	99.5	95.3	102.2	113.0	130.7	117.2
8	95.7	67.5	90.6	107.4	114.2	101.5	100.7	87.7
10	69.6	57.2	75.2	88.7	89.7	75.3	60.6	40.5
A	70.8	44.2	48.3	55.1	64.9	74.4	81.9	126.7
B	97.3	70.8	82.8	86.2	102.4	98.0	120.0	120.7
C	115.2	82.1	106.4	100.5	110.4	150.2	168.6	88.3
DESK NO. 18.—NORTHWEST EXPOSURE								
0	62.1	31.4	38.2	45.6	55.3	65.1	78.8	120.3
2	68.0	35.2	38.3	40.9	61.1	71.5	95.9	132.8
5	88.7	58.7	80.5	75.5	82.3	97.5	118.5	107.7
8	78.9	52.4	72.3	90.4	93.7	81.7	87.1	74.8
10	55.8	44.9	60.0	70.2	72.7	61.2	49.2	32 6
A	62.8	34.8	39.6	45.0	54.3	64.7	78.3	122.9
B	85.1	55.8	67.0	71.6	84.8	87.4	106.1	122.8
C	97.9	69.3	86.5	81.0	92.1	127.6	144.6	83.9

TABLE B.—*Hourly mean values of the illumination for each of 24 selected school desks, arranged for each hour and class of clouds, Hagerstown, Md., as derived from 7 mean monthly values for each hour, September 17, 1923, to April 15, 1924*—Continued

ROOM NO. 207

Clouds	Mean illumination in foot candles							
	All hours	9.40	10.40	11.40	12.40	1.40	2.40	3.40
DESK NO. 19.—SOUTHEAST EXPOSURE								
0	14.6	29.3	22.8	16.2	12.4	8.8	7.5	5.5
2	14.6	32.9	20.7	14.1	11.7	9.1	7.8	6.1
5	14.5	21.6	23.2	18.1	14.2	10.5	8.4	5.2
8	10.4	12.4	16.6	13.3	12.2	7.4	6.2	4.5
10	6.1	6.7	7.9	7.7	7.8	5.7	4.3	2.7
A	14.5	30.1	22.0	16.2	11.8	8.7	7.0	5.4
B	15.4	27.8	23.2	16.8	14.4	9.4	9.1	6.8
C	14.4	21.1	22.0	15.0	13.3	12.9	11.4	5.2
DESK NO. 20.—SOUTHEAST EXPOSURE								
0	20.4	45.3	33.1	22.1	16.3	11.1	8.7	6.1
2	21.1	56.0	28.3	19.8	16.3	11.1	9.1	7.2
5	18.7	28.5	30.8	23.8	18.4	13.0	10.3	6.0
8	13.8	19.3	22.3	17.7	15.1	9.3	7.6	5.1
10	7.5	8.9	9.5	9.3	9.5	6.8	5.1	3.1
A	20.6	48.0	33.3	22.1	15.7	11.0	8.3	6.0
B	21.2	41.3	33.6	23.9	19.4	11.8	10.8	7.6
C	19.3	34.3	29.8	19.9	15.9	15.7	12.9	6.6
DESK NO. 21.—SOUTHEAST EXPOSURE								
0	19.2	44.0	32.4	21.6	14.7	9.6	7.3	4.8
2	19.1	50.6	25.3	19.3	15.0	10.1	7.6	5.5
5	15.8	21.9	26.2	21.3	16.6	11.1	8.7	4.6
8	11.6	16.4	20.2	15.0	12.5	7.3	5.9	4.2
10	5.8	7.1	7.5	7.1	7.5	5.1	3.8	2.4
A	19.6	44.7	33.1	23.2	14.5	9.7	7.0	4.8
B	19.1	36.4	33.4	23.2	17.1	10.1	7.7	5.8
C	17.3	34.0	27.4	17.7	15.2	11.9	10.1	4.7
DESK NO. 22.—SOUTHEAST EXPOSURE								
0	122.4	242.7	227.0	173.4	99.3	55.2	37.0	22.4
2	133.4	251.4	281.4	162.6	112.3	59.1	39.5	27.7
5	148.0	258.6	254.9	219.3	130.6	78.4	61.3	32.6
8	111.6	139.1	207.0	159.9	119.5	66.9	55.7	32.8
10	52.4	67.0	70.6	67.4	64.9	44.0	31.8	21.1
A	127.9	254.3	235.6	185.1	97.5	60.7	37.9	24.4
B	148.1	283.0	290.7	185.1	124.1	72.0	49.5	33.1
C	153.7	311.7	248.6	185.3	116.6	106.1	74.3	33.4
DESK NO. 23.—SOUTHEAST EXPOSURE								
0	148.3	289.3	258.7	200.9	123.4	75.8	51.9	38.0
2	160.2	296.1	298.5	197.5	143.8	81.4	59.9	44.5
5	192.4	364.0	288.9	272.4	164.3	116.4	88.4	52.5
8	155.6	188.7	267.2	209.3	171.4	111.5	87.2	54.2
10	87.4	99.9	116.8	114.7	108.2	77.3	57.5	37.4
A	159.2	310.3	289.4	212.4	124.0	82.1	55.3	40.9
B	194.9	359.2	346.5	258.0	166.0	180.0	78.6	55.8
C	200.0	326.2	354.6	245.0	153.1	152.8	109.6	58.4
DESK NO. 24.—SOUTHEAST EXPOSURE								
0	107.6	264.6	164.7	116.8	81.5	54.4	41.0	30.1
2	112.2	269.2	178.7	109.0	91.2	59.0	44.8	33.8
5	148.3	365.0	213.0	162.6	111.1	81.3	64.8	40.6
8	114.0	152.1	178.8	145.3	124.3	85.5	68.4	43.9
10	70.8	84.2	91.3	92.0	84.7	64.9	47.8	30.5
A	108.8	254.9	178.4	121.4	79.0	56.3	39.7	31.9
B	143.0	343.1	225.8	145.8	109.9	71.8	59.4	45.3
C	145.0	278.2	234.0	148.0	102.1	114.5	91.2	46.7

TABLE C.—*Hourly mean values of the illumination ratio (means of 9 monthly values) for each of 24 selected school desks, arranged for each hour and class of clouds, Hagerstown, Md., September 17, 1923, to June 15, 1924*

ROOM NO. 107

Clouds	Inside-outside illumination ratio (daylight factor)							
	All hours	9.40	10.40	11.40	12.40	1.40	2.40	3.40
	DESK NO. 1.—SOUTHEAST EXPOSURE							
0	0.0395	0.0838	0.0631	0.0426	0.0294	0.0190	0.0175	0.0210
2	.0417	.0888	.0594	.0457	.0296	.0226	.0170	.0286
5	.0687	.1422	.1327	.0663	.0428	.0426	.0285	.0254
8	.0923	.1139	.1238	.1083	.0848	.0661	.0672	.0821
10	.0912	.1041	.0969	.0892	.0875	.0907	.0876	.0828
A	.0456	.0969	.0721	.0528	.0294	.0244	.0205	.0230
B	.0600	.1198	.0792	.0699	.0475	.0274	.0345	.0420
C	.0785	.1417	.0943	.0711	.0523	.0619	.0529	.0750
	DESK NO. 2.—SOUTHEAST EXPOSURE							
0	0.0421	0.0855	0.0681	0.0488	0.0335	0.0197	0.0180	0.0213
2	.0442	.0960	.0580	.0518	.0332	.0231	.0191	.0284
5	.0734	.1511	.1435	.0764	.0472	.0427	.0288	.0244
8	.0889	.1112	.1140	.1054	.0876	.0621	.0649	.0772
10	.0892	.0999	.0939	.0881	.0860	.0903	.0864	.0796
A	.0483	.0987	.0799	.0594	.0328	.0243	.0206	.0225
B	.0627	.1192	.0850	.0790	.0520	.0284	.0317	.0434
C	.0781	.1392	.0879	.0758	.0540	.0662	.0526	.0712
	DESK NO. 3.—SOUTHEAST EXPOSURE							
0	0.0368	0.0780	0.0614	0.0435	0.0295	0.0164	0.0138	0.0150
2	.0390	.0872	.0537	.0469	.0295	.0189	.0152	.0218
5	.0579	.1185	.1064	.0661	.0383	.0349	.0222	.0186
8	.0704	.0815	.0988	.0836	.0690	.0495	.0499	.0606
10	.0647	.0747	.0705	.0622	.0631	.0648	.0606	.0571
A	.0432	.0930	.0703	.0551	.0300	.0208	.0166	.0163
B	.0519	.0915	.0728	.0730	.0439	.0229	.0258	.0336
C	.0644	.1241	.0806	.0643	.0438	.0486	.0380	.0517
	DESK NO. 4.—SOUTHEAST EXPOSURE							
0	0.0049	0.0148	0.0067	0.0038	0.0028	0.0020	0.0023	0.0022
2	.0050	.0182	.0046	.0037	.0027	.0020	.0016	.0025
5	.0046	.0088	.0090	.0042	.0035	.0028	.0024	.0018
8	.0048	.0069	.0057	.0046	.0044	.0010	.0030	.0053
10	.0044	.0059	.0046	.0041	.0043	.0044	.0039	.0039
A	.0049	.0149	.0064	.0048	.0027	.0019	.0018	.0022
B	.0043	.0071	.0058	.0049	.0036	.0025	.0028	.0035
C	.0057	.0157	.0051	.0041	.0034	.0037	.0033	.0048
	DESK NO. 5.—SOUTHEAST EXPOSURE							
0	0.0055	0.0165	0.0071	0.0043	0.0032	0.0024	0.0024	0.0028
2	.0058	.0202	.0053	.0044	.0032	.0024	.0021	.0033
5	.0057	.0097	.0115	.0052	.0042	.0039	.0030	.0023
8	.0061	.0084	.0068	.0060	.0056	.0048	.0038	.0071
10	.0058	.0074	.0061	.0055	.0057	.0059	.0053	.0050
A	.0057	.0168	.0071	.0051	.0031	.0024	.0023	.0028
B	.0051	.0085	.0067	.0058	.0042	.0030	.0035	.0043
C	.0069	.0178	.0060	.0048	.0043	.0050	.0043	.0063
	DESK NO. 6.—SOUTHEAST EXPOSURE							
0	0.0045	0.0116	0.0062	0.0036	0.0028	0.0022	0.0023	0.0027
2	.0043	.0121	.0043	.0037	.0026	.0021	.0020	.0030
5	.0049	.0100	.0078	.0043	.0036	.0038	.0028	.0021
8	.0055	.0068	.0060	.0055	.0051	.0046	.0035	.0068
10	.0054	.0063	.0056	.0052	.0052	.0056	.0051	.0047
A	.0044	.0109	.0056	.0043	.0027	.0022	.0021	.0027
B	.0044	.0070	.0054	.0046	.0036	.0027	.0033	.0040
C	.0056	.0118	.0051	.0042	.0038	.0045	.0040	.0061

TABLE C.—*Hourly mean values of the illumination ratio (means of 9 monthly values) for each of 24 selected school desks, arranged for each hour and class of clouds, Hagerstown, Md., September 17, 1923, to June 15, 1924*—Continued

ROOM NO. 104

Clouds	Inside-outside illumination ratio (daylight factor)							
	All hours	9.40	10.40	11.40	12.40	1.40	2.40	3.40
DESK NO. 7—NORTHWEST EXPOSURE								
0	0.0034	0.0026	0.0024	0.0022	0.0027	0.0028	0.0040	0.0072
2	.0036	.0032	.0020	.0021	.0023	.0031	.0040	.0087
5	.0048	.0048	.0065	.0035	.0032	.0046	.0052	.0056
8	.0069	.0060	.0071	.0055	.0058	.0076	.0058	.0102
10	.0066	.0057	.0061	.0065	.0064	.0067	.0074	.0073
A	.0034	.0027	.0022	.0027	.0025	.0028	.0041	.0069
B	.0047	.0026	.0033	.0033	.0037	.0039	.0061	.0098
C	.0054	.0050	.0032	.0035	.0043	.0060	.0062	.0094
DESK NO. 8.—NORTHWEST EXPOSURE								
0	0.0035	0.0028	0.0026	0.0024	0.0028	0.0031	0.0038	0.0068
2	.0037	.0034	.0022	.0022	.0025	.0030	.0041	.0082
5	.0049	.0052	.0069	.0036	.0036	.0046	.0055	.0051
8	.0068	.0062	.0055	.0064	.0059	.0078	.0059	.0097
10	.0070	.0061	.0066	.0070	.0070	.0071	.0076	.0075
A	.0034	.0029	.0023	.0029	.0026	.0028	.0038	.0066
B	.0047	.0026	.0035	.0034	.0040	.0039	.0060	.0094
C	.0053	.0055	.0034	.0026	.0045	.0062	.0058	.0091
DESK NO. 9.—NORTHWEST EXPOSURE								
0	0.0026	0.0022	0.0020	0.0020	0.0025	0.0025	0.0028	0.0043
2	.0026	.0027	.0017	.0018	.0019	.0023	.0028	.0047
5	.0034	.0040	.0048	.0028	.0027	.0034	.0034	.0028
8	.0047	.0046	.0040	.0046	.0042	.0053	.0039	.0062
10	.0049	.0044	.0049	.0051	.0049	.0051	.0052	.0050
A	.0025	.0022	.0018	.0023	.0020	.0020	.0026	.0044
B	.0032	.0019	.0026	.0024	.0029	.0028	.0042	.0056
C	.0039	.0040	.0025	.0028	.0031	.0042	.0043	.0063
DESK NO. 10.—NORTHWEST EXPOSURE								
0	0.0106	0.0082	0.0072	0.0073	0.0082	0.0097	0.0130	0.0206
2	.0119	.0103	.0063	.0073	.0080	.0102	.0134	.0276
5	.0182	.0177	.0185	.0159	.0131	.0201	.0242	.0180
8	.0382	.0360	.0331	.0362	.0335	.0423	.0349	.0516
10	.0465	.0395	.0438	.0473	.0439	.0512	.0502	.0496
A	.0107	.0091	.0067	.0084	.0079	.0093	.0134	.0199
B	.0179	.0100	.0145	.0122	.0152	.0158	.0253	.0323
C	.0283	.0229	.0185	.0190	.0237	.0313	.0347	.0477
DESK NO. 11.—NORTHWEST EXPOSURE								
0	0.0222	0.0127	0.0114	0.0116	0.0143	0.0189	0.0295	0.0572
2	.0257	.0162	.0104	.0119	.0153	.0218	.0321	.0725
5	.0350	.0271	.0301	.0245	.0231	.0410	.0508	.0484
8	.0669	.0531	.0530	.0634	.0574	.0733	.0634	.1045
10	.0742	.0616	.0689	.0731	.0712	.0828	.0801	.0818
A	.0220	.0141	.0109	.0138	.0145	.0194	.0298	.0514
B	.0378	.0158	.0226	.0207	.0275	.0312	.0528	.0942
C	.0527	.0393	.0290	.0311	.0415	.0579	.0703	.1000
DESK NO. 12.—NORTHWEST EXPOSURE								
0	0.0244	0.0127	0.0113	0.0118	0.0145	0.0195	0.0321	0.0687
2	.0274	.0165	.0102	.0126	.0159	.0233	.0353	.0782
5	.0366	.0268	.0303	.0251	.0250	.0420	.0535	.0532
8	.0674	.0532	.0528	.0645	.0556	.0752	.0634	.1070
10	.0731	.0606	.0692	.0712	.0686	.0819	.0788	.0815
A	.0245	.0143	.0120	.0143	.0149	.0202	.0323	.0636
B	.0404	.0159	.0220	.0216	.0284	.0323	.0570	.1054
C	.0532	.0374	.0290	.0314	.0403	.0566	.0718	.1058

TABLE C.—*Hourly mean values of the illumination ratio (means of 9 monthly values) for each of 24 selected school desks, arranged for each hour and class of clouds, Hagerstown, Md., September 17, 1923, to June 15, 1924*—Continued

ROOM NO. 204

Clouds	Inside-outside illumination ratio (daylight factor)							
	All hours	9.40	10.40	11.40	12.40	1.40	2.40	3.40
	DESK NO. 13.—NORTHWEST EXPOSURE							
0	0.0028	0.0022	0.0021	0.0017	0.0021	0.0021	0.0033	0.0063
2	.0030	.0029	.0016	.0016	.0019	.0023	.0032	.0074
5	.0036	.0044	.0044	.0026	.0027	.0034	.0039	.0039
8	.0044	.0041	.0039	.0043	.0042	.0045	.0038	.0062
10	.0047	.0040	.0048	.0046	.0047	.0048	.0049	.0050
A	.0030	.0023	.0020	.0022	.0019	.0023	.0046	.0060
B	.0036	.0022	.0023	.0025	.0033	.0027	.0046	.0077
C	.0042	.0042	.0025	.0025	.0036	.0042	.0047	.0078
	DESK NO. 14.—NORTHWEST EXPOSURE							
0	0.0027	0.0024	0.0023	0.0019	0.0022	0.0020	0.0028	0.0052
2	.0028	.0030	.0018	.0017	.0019	.0021	.0029	.0063
5	.0037	.0046	.0049	.0028	.0028	.0034	.0038	.0035
8	.0045	.0042	.0042	.0045	.0042	.0046	.0038	.0062
10	.0048	.0040	.0045	.0047	.0049	.0049	.0053	.0051
A	.0026	.0024	.0021	.0023	0020	0021	.0029	.0052
B	.0035	.0023	.0029	.0025	.0033	.0027	.0045	.0063
C	.0041	.0043	.0026	.0027	.0035	.0041	.0044	.0073
	DESK NO. 15.—NORTHWEST EXPOSURE							
0	0.0017	0.0018	0.0016	0.0014	0.0015	0.0013	0.0017	0.0028
2	.0017	.0022	.0014	.0013	.0012	.0014	.0017	.0030
5	.0023	.0032	.0033	.0018	.0018	.0020	.0022	.0016
8	.0028	.0029	.0027	.0028	.0025	.0030	.0022	.0036
10	.0030	.0025	.0028	.0030	.0030	.0031	.0031	.0033
A	.0017	.0017	.0014	.0016	.0014	.0013	.0017	.0026
B	.0021	.0015	.0016	.0017	.0021	.0016	.0027	.0032
C	.0024	.0026	.0016	.0016	.0021	.0025	.0027	.0040
	DESK NO. 16.—NORTHWEST EXPOSURE							
0	0.0073	0.0064	0.0057	0.0054	0.0060	0.0065	0.0082	0.0132
2	.0086	.0080	.0047	.0055	.0059	.0070	.0107	.0184
5	.0134	.0169	.0165	.0111	.0097	.0110	0168	.0117
8	.0249	.0247	.0229	.0253	.0216	.0262	.0229	.0308
10	.0320	.0272	.0297	.0325	.0297	.0365	.0316	.0336
A	.0074	.0066	.0052	.0062	.0056	.0064	.0085	.0134
B	.0122	.0073	.0101	.0085	.0112	.0117	.0163	.0203
C	.0192	.0172	.0131	.0134	.0166	.0200	.0225	.0316
	DESK NO. 17.—NORTHWEST EXPOSURE							
0	0.0210	0.0121	0.0112	0.0113	0.0135	0.0170	0.0263	0.0556
2	.0243	.0157	.0092	.0115	.0150	.0197	.0302	.0690
5	.0342	.0299	.0300	.0228	.0236	.0325	.0500	.0504
8	.0590	.0513	.0475	.0571	.0483	.0656	.0546	.0886
10	.0690	.0582	.0634	.0702	.0646	.0766	.0738	.0760
A	.0212	.0136	.0105	.0133	.0143	.0178	.0267	.0519
B	.0331	.0147	.0215	.0192	.0253	.0267	.0446	.0797
C	.0487	.0425	.0281	.0296	.0387	.0525	.0619	.0874
	DESK NO. 18.—NORTHWEST EXPOSURE							
0	0.0196	0.0097	0.0090	0.0091	0.0114	0.0148	0.0245	0.0584
2	.0226	.0126	.0075	.0094	.0128	.0175	.0280	.0702
5	.0307	.0238	.0233	.0190	.0195	.0282	.0438	.0574
8	.0484	.0408	.0381	.0475	.0404	.0524	.0465	.0734
10	.0550	.0450	.0510	.0547	.0518	.0616	.0593	.0614
A	.0191	.0108	.0087	.0109	.0117	.0154	.0254	.0505
B	.0302	.0111	.0166	.0158	.0209	.0232	.0405	.0832
C	.0410	.0340	.0228	.0237	.0304	.0435	.0533	.0796

TABLE C.—*Hourly mean values of the illumination ratio (means of 9 monthly values) for each of 24 selected school desks, arranged for each hour and class of clouds, Hagerstown, Md., September 17, 1923, to June 15, 1924*—Continued

ROOM NO. 207

Clouds	Inside-outside illumination ratio (daylight factor)							
	All hours	9.40	10.40	11.40	12.40	1.40	2.40	3.40
DESK NO. 19.—SOUTHEAST EXPOSURE								
0	0.0038	0.0085	0.0051	0.0031	0.0025	0.0019	0.0023	0.0030
2	.0039	.0111	.0037	.0029	.0022	.0021	.0022	.0032
5	.0049	.0096	.0089	.0041	.0036	.0030	.0028	.0021
8	.0059	.0100	.0069	.0055	.0048	.0045	.0036	.0058
10	.0055	.0061	.0059	.0055	.0054	.0057	.0052	.0049
A	.0039	.0091	.0049	.0036	.0024	.0021	.0021	.0029
B	.0042	.0068	.0046	.0040	.0038	.0024	.0036	.0040
C	.0052	.0097	.0047	.0038	.0040	.0043	.0041	.0055
DESK NO. 20.—SOUTHEAST EXPOSURE								
0	0.0052	0.0134	0.0074	0.0041	0.0032	0.0024	0.0026	0.0032
2	.0059	.0196	.0054	.0042	.0033	.0025	.0026	.0037
5	.0059	.0124	.0095	.0055	.0043	.0036	.0034	.0025
8	.0074	.0133	.0087	.0073	.0061	.0052	.0045	.0068
10	.0066	.0080	.0071	.0065	.0064	.0067	.0061	.0057
A	.0055	.0145	.0074	.0049	.0032	.0026	.0025	.0031
B	.0055	.0095	.0064	.0058	.0050	.0030	.0042	.0048
C	.0068	.0146	.0066	.0051	.0048	.0048	.0046	.0068
DESK NO. 21.—SOUTHEAST EXPOSURE								
0	0.0049	0.0133	0.0072	0.0040	0.0030	0.0021	0.0022	0.0025
2	.0054	.0186	.0049	.0040	.0031	.0023	.0022	.0028
5	.0053	.0102	.0103	.0051	.0038	.0031	.0028	.0020
8	.0062	.0112	.0076	.0061.	.0051	.0043	.0035	.0056
10	.0051	.0063	.0054	.0048	.0048	.0051	.0046	.0044
A	.0051	.0137	.0073	.0047	.0029	.0022	.0021	.0025
B	.0047	.0074	.0062	.0056	.0044	.0024	.0032	.0039
C	.0060	.0146	.0060	.0046	.0041	.0041	.0036	.0051
DESK NO. 22.—SOUTHEAST EXPOSURE								
0	0.0289	0.0668	0.0483	0.0325	0.0204	0.0119	0.0110	0.0115
2	.0314	.0790	.0465	.0335	.0216	.0131	.0109	.0154
5	.0476	.1174	.0857	.0477	.0286	.0223	.0188	.0127
8	.0534	.0787	.0795	.0572	.0473	.0403	.0297	.0410
10	.0453	.0569	.0480	.0460	.0428	.0456	.0398	.0380
A	.0314	.0743	.0499	.0391	.0191	.0136	.0116	.0120
B	.0391	.0683	.0590	.0552	.0332	.0158	.0184	.0236
C	.0490	.1168	.0508	.0440	.0323	.0357	.0280	.0351
DESK NO. 23.—SOUTHEAST EXPOSURE								
0	0.0364	0.0829	0.0570	0.0378	0.0252	0.0164	0.0158	0.0194
2	.0389	.0955	.0190	.0399	.0276	.0183	.0168	.0252
5	.0623	.1414	.1145	.0611	.0366	.0325	.0277	.0225
8	.0786	.1084	.1162	.0854	.0699	.0660	.0473	.0568
10	.0794	.0920	.0861	.0819	.0753	.0783	.0734	.0689
A	.0397	.0907	.0604	.0454	.0251	.0189	.0169	.0205
B	.0503	.0874	.0688	.0606	.0441	.0230	.0293	.0390
C	.0684	.1369	.0762	.0595	.0488	.0549	.0419	.0606
DESK NO. 24.—SOUTHEAST EXPOSURE								
0	0.0274	0.0754	0.0376	0.0227	0.0166	0.0119	0.0122	0.0157
2	.0288	.0858	.0307	.0219	.0171	.0134	.0126	.0199
5	.0507	.1374	.0911	.0392	.0263	.0235	.0202	.0174
8	.0612	.0949	.0812	.0646	.0522	.0530	.0370	.0454
10	.0663	.0786	.0694	.0685	.0612	.0678	.0613	.0571
A	.0286	.0766	.0387	.0266	.0162	.0133	.0122	.0167
B	.0404	.0915	.0464	.0347	.0398	.0166	.0230	.0308
C	.0491	.0928	.0510	.0384	.0366	.0417	.0345	.0488

TABLE D.—*Monthly mean values of the illumination ratio (means of values for only 4 or 5 certain hours[1]) for each of 24 selected school desks, arranged for each month and class of clouds, Hagerstown, Md., September 17, 1923, to June 15, 1924*

ROOM NO. 107

Clouds	Inside-outside illumination ratio (daylight factor)									
	All months	Oct.[2]	Nov.[2]	Dec.[2]	Jan.[2]	Feb.[2]	Mar.[2]	Apr.[2]	May[2]	June[2]
DESK NO. 1.—SOUTHEAST EXPOSURE										
0	0.0209	0.0147	0.0171	0.0245	0.0330	0.0336	0.0320	0.0155	0.0101	0.0086
2	.0244	.0171	.0255	.0375	.0450	.0296	.0221	.0196	.0108	.0120
5	.0407	.0299	.0459	.0605	.0602	.0586	.0452	.0314	.0201	.0146
8	.0766	.0606	.0686	.0899	.1223	.0935	.0768	.0568	.0619	.0587
10	.0871	.0667	.0740	.0810	.1050	.0952	.1082	.0908	.0952	.0680
A	0243	.0157	.0200	.0290	.0359	.0394	.0224	.0259	.0129	.0178
B	.0391	.0226	----	.0561	.0541	.0520	.0429	.0403	.0286	.0165
C	.0645	----	.0476	.0783	.0805	.0756	.0608	.0528	.0596	.0606
DESK NO. 2.—SOUTHEAST EXPOSURE										
0	0.0222	0.0154	0.0178	0.0258	0.0364	0.0372	0.0334	0.0149	0.0100	0.0088
2	0256	.0181	.0258	.0362	.0493	.0346	.0239	.0204	.0103	.0121
5	.0438	.0307	.0495	.0602	.0578	.0688	.0487	.0314	.0189	.0280
8	.0717	.0546	.0714	.0844	.1187	.0910	.0790	.0552	.0616	.0297
10	.0856	.0676	.0706	.0772	.1047	.0958	.1064	.0903	.0912	.0663
A	.0250	.0168	.0219	.0298	.0343	.0442	.0244	.0236	.0126	.0178
B	.0406	.0221	----	.0581	.0538	.0555	.0464	.0416	.0296	.0175
C	0640	----	.0488	.0800	.0727	.0758	.0629	.0544	.0576	.0602
DESK NO. 3.—SOUTHEAST EXPOSURE										
0	0.0178	0.0120	0.0138	0.0209	0.0298	0.0315	0.0268	0.0114	0.0074	0.0070
2	.0213	.0181	.0221	.0310	.0395	.0302	.0184	.0157	.0079	.0092
5	.0338	.0261	.0344	.0576	.0451	.0536	.0391	.0234	.0149	.0104
8	.0586	.0403	.0514	.0715	.0959	.0729	.0654	.0402	.0425	.0475
10	.0614	.0471	.0485	.0581	.0760	.0701	.0766	.0635	.0662	.0462
A	.0209	.0131	.0155	.0252	.0326	.0376	.0202	.0211	.0102	.0129
B	.0334	.0187	----	.0501	.0451	.0477	.0372	.0330	.0226	.0129
C	.0475	----	.0309	.0678	.0550	.0596	.0475	.0369	.0410	.0414
DESK NO. 4.—SOUTHEAST EXPOSURE										
0	0.0022	0.0013	0.0018	0.0029	0.0039	0.0034	0.0028	0.0016	0.0012	0.0008
2	.0022	.0014	.0020	.0031	.0042	.0028	.0023	.0018	.0012	.0008
5	.0032	.0020	.0058	.0043	.0038	.0043	.0039	.0025	.0015	.0010
8	.0042	.0026	.0040	.0059	.0064	.0046	.0056	.0036	.0025	.0024
10	.0041	.0022	.0035	.0043	.0052	.0044	.0065	.0050	.0037	.0021
A	.0021	.0014	.0020	.0033	.0034	.0029	.0022	.0017	.0014	.0010
B	.0031	.0020	----	.0049	.0046	.0035	.0039	.0027	.0020	.0013
C	.0043	----	.0032	.0056	.0080	.0042	.0048	.0031	.0032	.0023
DESK NO. 5.—SOUTHEAST EXPOSURE										
0	0.0026	0.0016	0.0024	0.0033	0.0040	0.0040	0.0034	0.0019	0.0017	0.0012
2	.0027	.0017	.0026	.0038	.0050	.0034	.0030	.0024	.0016	.0011
5	.0041	.0023	.0070	.0050	.0052	.0054	.0050	.0032	.0021	.0013
8	.0054	.0032	.0052	.0073	.0086	.0057	.0072	.0048	.0032	.0032
10	.0055	.0028	.0047	.0055	.0071	.0057	.0087	.0068	.0050	.0029
A	.0026	.0016	.0026	.0043	.0042	.0032	.0027	.0021	.0018	.0014
B	.0038	.0022	----	.0057	.0056	.0043	.0048	.0033	.0026	.0016
C	.0056	----	.0046	.0070	.0097	.0055	.0063	.0042	.0042	.0030
DESK NO. 6.—SOUTHEAST EXPOSURE										
0	0.0024	0.0015	0.0022	0.0031	0.0037	0.0037	0.0032	0.0018	0.0016	0.0010
2	.0024	.0015	.0023	0032	0045	.0030	.0026	.0022	.0014	.0010
5	.0037	.0020	.0061	.0044	.0050	.0046	.0052	.0029	.0019	.0011
8	.0050	.0029	.0048	.0071	.0081	.0055	.0068	.0042	.0031	.0027
10	.0051	.0024	.0041	.0052	.0068	.0054	.0084	.0065	.0050	.0024
A	0024	.0015	.0024	.0040	.0040	.0029	.0024	.0019	.0016	.0012
B	.0034	.0018	----	.0051	.0048	.0037	.0047	.0030	.0025	.0015
C	.0051	----	.0044	.0063	.0092	.0051	.0056	.0039	.0037	.0025

[1] Hours 9.40 a. m. to 1.40 p. m. for rooms 104 and 204, and hours 12.40 p. m. to 3.40 p. m. for rooms 107 and 207.

[2] Interval ending on the 15th day of the indicated month.

TABLE D.—*Monthly mean values of the illumination ratio (means of values for only 4 or 5 certain hours [1]) for each of 24 selected school desks, arranged for each month and class of clouds, Hagerstown Md., September 17, 1923, to June 15, 1924*—Continued

ROOM NO. 104

Clouds	Inside-outside illumination ratio (daylight factor)									
	All months	Oct.[2]	Nov.[2]	Dec.[2]	Jan.[2]	Feb.[2]	Mar.[2]	Apr.[2]	May[2]	June[2]
DESK NO. 7.—NORTHWEST EXPOSURE										
0	0.0025	0.0017	0.0020	0.0028	0.0034	0.0035	0.0042	0.0018	0.0018	0.0015
2	.0026	.0019	.0022	.0034	.0038	.0031	.0026	.0025	.0018	.0017
5	.0043	.0030	.0038	.0041	.0046	.0056	.0061	.0060	.0034	.0023
8	.0058	.0034	.0043	.0051	.0065	.0078	.0088	.0059	.0052	.0043
10	.0063	.0040	.0050	.0059	.0070	.0065	.0098	.0071	.0065	.0047
A	.0026	.0017	.0019	.0032	.0032	.0027	.0044	.0021	.0023	.0016
B	.0034	.0023	.0024	.0052	.0034	.0035	.0046	.0032	.0024	.0034
C	.0044	----------	.0040	.0054	.0042	.0054	.0056	.0032	.0037	.0039
DESK NO. 8.—NORTHWEST EXPOSURE										
0	0.0027	0.0018	0.0021	0.0030	0.0037	0.0036	0.0045	0.0019	0.0022	0.0015
2	.0027	.0019	.0022	.0034	.0041	.0034	.0028	.0026	.0019	.0017
5	.0046	.0034	.0042	.0041	.0050	.0058	.0067	.0064	.0036	.0023
8	.0051	.0036	.0045	.0076	.0069	.0079	.0090	.0060	.0052	.0045
10	.0068	.0042	.0054	.0065	.0076	.0072	.0105	.0079	.0071	.0046
A	.0027	.0018	.0019	.0034	.0035	.0028	.0047	.0023	.0022	.0016
B	.0035	.0023	.0024	.0054	.0036	.0036	.0050	.0035	.0025	.0033
C	.0046	----------	.0040	.0058	.0044	.0050	.0052	.0035	.0037	.0040
DESK NO. 9.—NORTHWEST EXPOSURE										
0	0.0022	0.0013	0.0017	0.0024	0.0031	0.0035	0.0037	0.0016	0.0014	0.0010
2	.0021	.0014	.0018	.0029	.0033	.0027	.0021	.0019	.0015	.0012
5	.0033	.0021	.0034	.0032	.0038	.0048	.0041	.0045	.0025	.0014
8	.0044	.0023	.0034	.0055	.0052	.0061	.0067	.0044	.0036	.0025
10	.0049	.0027	.0037	.0048	.0058	.0053	.0082	.0059	.0046	.0027
A	.0021	.0012	.0015	.0027	.0029	.0022	.0038	.0017	.0016	.0011
B	.0026	.0015	.0019	.0041	.0029	.0027	.0038	.0026	.0017	.0020
C	.0033	----------	.0027	.0043	.0039	.0033	.0047	.0025	.0026	.0023
DESK NO. 10.—NORTHWEST EXPOSURE										
0	0.0081	0.0052	0.0061	0.0087	0.0117	0.0109	0.0140	0.0052	0.0058	0.0049
2	.0085	.0064	.0072	.0109	.0126	.0122	.0077	.0067	.0065	.0062
5	.0171	.0129	.0168	.0160	.0187	.0216	.0262	.0158	.0170	.0088
8	.0349	.0218	.0335	.0474	.0380	.0485	.0441	.0286	.0276	.0248
10	.0451	.0279	.0400	.0465	.0575	.0499	.0589	.0438	.0486	.0331
A	.0083	.0061	.0059	.0101	.0109	.0111	.0122	.0067	.0051	.0057
B	.0135	.0087	.0074	.0184	.0132	.0121	.0172	.0146	.0128	.0172
C	.0230	----------	.0244	.0276	.0225	.0207	.0262	.0186	.0206	.0232
DESK NO. 11.—NORTHWEST EXPOSURE										
0	0.0137	0.0101	0.0105	0.0141	0.0188	0.0176	0.0239	0.0088	0.0097	0.0094
2	.0153	.0131	.0160	.0186	.0203	.0216	.0133	.0109	.0121	.0116
5	.0294	.0252	.0306	.0289	.0290	.0331	.0396	.0286	.0351	.0148
8	.0583	.0350	.0588	.0756	.0629	.0724	.0786	.0506	.0480	.0427
10	.0715	.0465	.0652	.0712	.0869	.0772	.0917	.0880	.0794	.0575
A	.0146	.0120	.0108	.0165	.0175	.0189	.0208	.0117	.0119	.0110
B	.0237	.0146	.0128	.0338	.0240	.0198	.0280	.0280	.0230	.0296
C	.0403	----------	.0469	.0444	.0352	.0410	.0441	.0323	.0360	.0423
DESK NO. 12.—NORTHWEST EXPOSURE										
0	0.0138	0.0101	0.0106	0.0143	0.0192	0.0181	0.0245	0.0086	0.0103	0.0089
2	.0159	.0133	.0165	.0193	.0215	.0235	.0139	.0121	.0120	.0111
5	.0303	.0273	.0311	.0295	.0327	.0314	.0398	.0320	.0333	.0154
8	.0593	.0317	.0573	.0784	.0623	.0752	.0788	.0496	.0492	.0512
10	.0703	.0437	.0627	.0712	.0881	.0783	.0909	.0678	.0781	.0520
A	.0151	.0118	.0131	.0174	.0176	.0194	.0221	.0126	.0114	.0107
B	.0244	.0156	.0136	.0348	.0267	.0208	.0290	.0278	.0239	.0273
C	.0399	----------	.0460	.0469	.0366	.0418	.0439	.0314	.0337	.0386

[1] Hours 9.40 a. m. to to 1.40 p. m. for rooms 104 and 204, and hours 12.40 p. m. to 3.40 p. m. for rooms 107 and 207.

[2] Interval ending on the 15th day of the indicated month.

TABLE D.—*Monthly mean values of the illumination ratio (means of values for only 4 or 5 certain hours [1]) for each of 24 selected school desks, arranged for each month and class of clouds, Hagerstown, Md., September 17, 1923, to June 15, 1924*—Continued

ROOM No. 204

Clouds	Inside-outside illumination ratio (daylight factor)									
	All months	Oct.[2]	Nov.[2]	Dec.[2]	Jan.[2]	Feb.[2]	Mar.[2]	Apr.[2]	May [2]	June [2]
DESK NO. 13.—NORTHWEST EXPOSURE										
0	0.0020	0.0013	0.0016	0.0025	0.0029	0.0029	0.0030	0.0015	0.0013	0.0012
	.0021	.0014	.0021	.0030	.0033	.0024	.0019	.0020	.0013	.0011
5	.0034	.0023	.0032	.0036	.0043	.0052	.0042	.0038	.0024	.0017
8	.0041	.0024	.0036	.0051	.0048	.0052	.0058	.0033	.0034	.0032
10	.0046	.0030	.0037	.0056	.0052	.0047	.0065	.0049	.0046	.0031
A	.0021	.0014	.0016	.0029	.0029	.0021	.0035	.0018	.0017	.0013
B	.0026	.0017	.0020	.0046	.0032	.0028	.0031	.0024	.0015	.0023
C	.0033	----------	.0032	.0043	.0033	.0032	.0044	.0022	.0028	.0028
DESK NO. 14.—NORTHWEST EXPOSURE										
0	0.0021	0.0013	0.0017	0.0027	0.0032	0.0031	0.0031	0.0015	0.0013	0.0011
2	.0021	.0013	.0021	.0030	.0035	.0026	.0020	.0020	.0014	.0011
5	.0035	.0021	.0029	.0034	.0045	.0054	.0048	.0046	.0024	.0018
8	.0042	.0023	.0033	.0051	.0050	.0056	.0062	.0040	.0034	.0032
10	.0046	.0028	.0037	.0049	.0055	.0049	.0069	.0051	.0047	.0031
A	.0022	.0013	.0016	.0031	.0031	.0022	.0037	.0018	.0018	.0012
B	.0028	.0016	.0018	.0056	.0033	.0032	.0034	.0025	.0015	.0022
C	.0034	----------	.0029	.0043	.0039	.0036	.0049	.0022	.0028	.0026
DESK NO. 15.—NORTHWEST EXPOSURE										
0	0.0015	0.0008	0.0011	0.0021	0.0023	0.0023	0.0022	0.0011	0.0009	0.0006
2	.0015	.0008	.0015	.0021	.0026	.0019	.0015	.0014	.0009	.0006
5	.0023	.0012	.0021	.0022	.0032	.0038	.0034	.0030	.0014	.0008
8	.0027	.0012	.0019	.0037	.0033	.0041	.0039	.0022	.0022	.0015
10	.0029	.0014	.0022	.0031	.0038	.0033	.0046	.0033	.0028	.0015
A	.0015	.0008	.0010	.0021	.0023	.0015	.0026	.0012	.0011	.0006
B	.0017	.0009	.0014	.0030	.0023	.0022	.0020	.0017	.0010	.0012
C	.0021	----------	.0017	.0028	.0024	.0022	.0030	.0015	.0016	.0013
DESK NO. 16.—NORTHWEST EXPOSURE										
0	0.0059	0.0037	0.0042	0.0068	0.0088	0.0085	0.0103	0.0038	0.0038	0.0036
2	.0063	.0046	.0052	.0088	.0091	.0093	.0058	.0049	.0046	.0040
5	.0125	.0103	.0094	.0110	.0131	.0198	.0177	.0133	.0103	.0077
8	.0234	.0149	.0233	.0303	.0246	.0322	.0290	.0187	.0206	.0172
10	.0311	.0213	.0271	.0323	.0395	.0342	.0384	.0310	.0343	.0221
A	.0060	.0043	.0043	.0079	.0079	.0074	.0092	.0047	.0040	.0042
B	.0098	.0058	.0049	.0140	.0097	.0082	.0125	.0134	.0078	.0116
C	.0155	----------	.0146	.0189	.0162	.0142	.0200	.0082	.0140	.0179
DESK NO. 17.—NORTHWEST EXPOSURE										
0	0.0129	0.0097	0.0097	0.0130	0.0182	0.0169	0.0228	0.0081	0.0090	0.0091
2	.0144	.0129	.0142	.0176	.0192	.0202	.0123	.0120	.0106	.0105
5	.0279	.0233	.0312	.0275	.0271	.0391	.0337	.0272	.0255	.0164
8	.0524	.0317	.0495	.0634	.0533	.0696	.0676	.0494	.0457	.0415
10	.0666	.0490	.0599	.0677	.0787	.0714	.0792	.0681	.0723	.0533
A	.0139	.0117	.0099	.0162	.0167	.0181	.0198	.0108	.0107	.0112
B	.0216	.0142	.0110	.0304	.0238	.0178	.0255	.0234	.0197	.0282
C	.0382	----------	.0390	.0435	.0376	.0410	.0422	.0280	.0326	.0419
DESK NO. 18.—NORTHWEST EXPOSURE										
0	0.0107	0.0082	0.0082	0.0107	0.0150	0.0142	0.0185	0.0069	0.0072	0.0074
2	.0121	.0108	.0126	.0146	.0160	.0162	.0105	.0101	.0094	.0087
5	.0231	.0212	.0263	.0239	.0234	.0303	.0259	.0220	.0220	.0130
8	.0428	.0246	.0380	.0505	.0442	.0569	.0577	.0420	.0388	.0324
10	.0528	.0368	.0467	.0547	.0636	.0572	.0638	.0565	.0551	.0409
A	.0115	.0099	.0082	.0140	.0132	.0147	.0165	.0092	.0095	.0083
B	.0178	.0113	.0092	.0266	.0208	.0143	.0210	.0190	.0166	.0214
C	.0314	----------	.0326	.0358	.0299	.0363	.0344	.0234	.0268	.0319

[1] Hours 9.40 a.m. to 1.40 p.m. for rooms 104 and 204, and hours 12.40 p.m. to 3.40 p.m. for rooms 107 and 207.

[2] Interval ending on the 15th day of the indicated month.

TABLE D.—*Monthly mean values of the illumination ratio (means of values for only 4 or 5 certain hours [1]) for each of 24 selected school desks, arranged for each month and class of clouds, Hagerstown, Md., September 17, 1923, to June 15, 1924*—Continued

ROOM NO. 207

Clouds	Inside-outside illumination ratio (daylight factor)									
	All months	Oct.[2]	Nov.[2]	Dec.[2]	Jan.[2]	Feb.[2]	Mar.[2]	Apr.[2]	May [2]	June [2]
DESK NO. 19.—SOUTHEAST EXPOSURE										
0	0.0024	0.0015	0.0021	0.0030	0.0037	0.0035	0.0030	0.0020	0.0014	0.0010
2	.0024	.0016	.0023	.0036	.0046	.0025	.0025	.0021	.0015	.0012
5	.0032	.0022	.0046	.0040	.0045	.0037	.0035	.0028	.0017	.0018
8	.0047	.0035	.0038	.0066	.0070	.0048	.0054	.0030	.0035	.0046
10	.0053	.0034	.0045	.0052	.0060	.0050	.0072	.0066	.0058	.0040
A	.0024	.0014	.0023	.0038	.0039	.0028	.0024	.0018	.0016	.0014
B	.0033	.0022	---	.0053	.0052	.0030	.0040	.0034	.0020	.0016
C	.0048	---	.0043	.0060	.0068	.0047	.0049	.0041	.0040	.0036
DESK NO. 20.—SOUTHEAST EXPOSURE										
0	0.0028	0.0018	0.0025	0.0032	0.0044	0.0043	0.0037	0.0020	0.0018	0.0012
2	.0030	.0020	.0029	.0041	.0055	.0039	.0030	.0024	.0017	.0015
5	.0040	.0029	.0058	.0050	.0050	.0050	.0045	.0034	.0023	.0020
8	.0057	.0041	.0044	.0083	.0083	.0060	.0062	.0038	.0042	.0056
10	.0062	.0042	.0052	.0060	.0069	.0061	.0084	.0075	.0067	.0048
A	.0028	.0018	.0026	.0044	.0043	.0034	.0030	.0022	.0019	.0020
B	.0043	.0027	---	.0067	.0062	.0048	.0051	.0041	.0025	.0020
C	.0059	---	.0047	.0072	.0104	.0048	.0060	.0048	.0048	.0044
DESK NO. 21.—SOUTHEAST EXPOSURE										
0	0.0024	0.0016	0.0020	0.0030	0.0039	0.0038	0.0030	0.0016	0.0014	0.0010
2	.0026	.0018	.0025	.0038	.0048	.0034	.0023	.0020	.0014	.0012
5	.0035	.0020	.0053	.0044	.0044	.0050	.0038	.0027	.0018	.0017
8	.0047	.0034	.0036	.0069	.0074	.0050	.0052	.0028	.0032	.0046
10	.0047	.0034	.0040	.0045	.0054	.0044	.0062	.0054	.0051	.0037
A	.0024	.0016	.0022	.0037	.0040	.0032	.0025	.0018	.0015	.0014
B	.0036	.0024	---	.0058	.0051	.0043	.0041	.0031	.0020	.0016
C	.0047	---	.0040	.0063	.0080	.0039	.0044	.0036	.0037	.0034
DESK NO. 22.—SOUTHEAST EXPOSURE										
0	0.0131	0.0098	0.0104	0.0145	0.0228	0.0238	0.0189	0.0074	0.0052	0.0051
2	.0152	.0128	.0155	.0213	.0290	.0218	.0136	.0102	.0062	.0068
5	.0244	.0216	.0339	.0340	.0268	.0349	.0263	.0180	.0141	.0098
8	.0408	.0330	.0351	.0506	.0684	.0476	.0415	.0232	.0252	.0430
10	.0417	.0332	.0372	.0404	.0496	.0420	.0482	.0416	.0470	.0357
A	.0141	.0110	.0119	.0171	.0212	.0256	.0149	.0089	.0074	.0087
B	.0244	.0152	---	.0419	.0315	.0355	.0252	.0226	.0136	.0099
C	.0343	---	.0268	.0460	.0427	.0374	.0342	.0306	.0277	.0292
DESK NO. 23.—SOUTHEAST EXPOSURE										
0	0.0185	0.0139	0.0156	0.0210	0.0301	0.0306	0.0277	0.0112	0.0082	0.0080
2	.0219	.0167	.0212	.0304	.0425	.0282	.0204	.0166	.0101	.0106
5	.0339	.0292	.0435	.0438	.0434	.0435	.0371	.0291	.0188	.0168
8	.0622	.0559	.0608	.0529	.1048	.0728	.0606	.0396	.0441	.0679
10	.0740	.0549	.0688	.0684	.0900	.0737	.0863	.0776	.0792	.0667
A	.0204	.0149	.0179	.0269	.0303	.0325	.0210	.0132	.0115	.0152
B	.0355	.0219	---	.0551	.0442	.0494	.0382	.0350	.0224	.0168
C	.0540	---	.0412	.0698	.0630	.0535	.0546	.0481	.0496	.0520
DESK NO. 24.—SOUTHEAST EXPOSURE										
0	0.0137	0.0104	0.0119	0.0159	0.0221	0.0210	0.0205	0.0084	0.0064	0.0064
2	.0156	.0120	.0150	.0234	.0296	.0174	.0146	.0124	.0076	.0086
5	.0243	.0206	.0283	.0300	.0306	.0320	.0253	.0219	.0157	.0139
8	.0483	.0438	.0456	.0407	.0784	.0565	.0456	.0289	.0384	.0566
10	.0619	.0444	.0568	.0598	.0763	.0607	.0719	.0641	.0679	.0549
A	.0146	.0100	.0136	.0195	.0218	.0206	.0144	.0099	.0086	.0128
B	.0252	.0169	---	.0382	.0332	.0290	.0278	.0261	.0170	.0132
C	.0424	---	.0356	.0507	.0496	.0431	.0420	.0362	.0398	.0423

[1] Hours 9.40 a. m. to 1.40 p. m. for rooms 104 and 204, and hours 12.40 p. m. to 3.40 p. m. for rooms 107 and 207.

[2] In terval ending on the 15th day of the indicated month.

TABLE E.—*Hourly mean values of the sky brightness ratio (means of 9 monthly values) for each of 24 selected school desks, arranged for each hour and class of clouds, Hagerstown, Md., September 17, 1923, to June 15, 1924*

ROOM NO. 107

Clouds	Inside-illumination sky brightness ratio							
	All hours	9.40	1.040	11.40	12.40	1.40	2.40	3.40
DESK NO. 1.—SOUTHEAST EXPOSURE								
0	0.294	0.632	0.513	0.345	0.240	0.109	0.119	0.100
2	.309	.609	.586	.391	.218	.147	.116	.099
5	.199	.392	.276	.264	.150	.134	.107	.069
8	.121	.179	.164	.157	.114	.079	.082	.074
10	.075	.093	.083	.077	.075	.068	.066	.066
A	.310	.643	.572	.358	.221	.168	.115	.090
B	.228	.358	.423	.306	.156	.151	.114	.086
C	.139	.248	.226	.129	.122	.099	.078	.072
DESK NO. 2.—SOUTHEAST EXPOSURE								
0	0.321	0.639	0.548	0.412	0.273	0.150	0.124	0.101
2	.325	.617	.583	.455	.242	.156	.124	.098
5	.214	.446	.286	.291	.164	.139	.102	.068
8	.120	.185	.149	.152	.119	.078	.080	.074
10	.074	.089	.080	.075	.074	.069	.064	.064
A	.326	.613	.611	.414	.263	.167	.119	.092
B	.248	.409	.452	.363	.167	.161	.097	.087
C	.141	.245	.220	.139	.131	.105	.077	.070
DESK NO. 3.—SOUTHEAST EXPOSURE								
0	0.283	0.588	0.499	0.366	0.243	0.122	0.092	0.071
2	.283	.555	.514	.403	.214	.126	.094	.072
5	.181	.410	.227	.240	.137	.114	.088	.053
8	.095	.141	.128	.119	.102	.062	.059	.054
10	.054	.071	.060	.056	.054	.048	.046	.044
A	.294	.583	.556	.381	.229	.147	.094	.066
B	.208	.293	.406	.343	.136	.135	.078	.066
C	.120	.229	.200	.114	.112	.080	.054	.050
DESK NO. 4.—SOUTHEAST EXPOSURE								
0	0.036	0.104	0.052	0.031	0.023	0.015	0.013	0.011
2	.032	.092	.048	.031	.020	.014	.012	.010
5	.013	.025	.022	.016	.010	.010	.007	.004
8	.007	.011	.009	.007	.007	.005	.004	.005
10	.004	.006	.004	.004	.004	.003	.003	.003
A	.034	.095	.053	.032	.021	.014	.012	.010
B	.017	.018	.035	.024	.012	.013	.009	.008
C	.014	.040	.013	.019	.010	.007	.003	.005
DESK NO. 5.—SOUTHEAST EXPOSURE								
0	0.039	0.104	0.057	0.036	0.027	0.018	0.017	0.014
2	.038	.102	.052	.038	.026	.018	.016	.012
5	.016	.030	.022	.019	.013	.012	.009	.005
8	.009	.015	.010	.008	.009	.006	.006	.006
10	.005	.007	.005	.005	.005	.005	.004	.004
A	.038	.106	.055	.035	.025	.017	.015	.012
B	.020	.022	.038	.029	.015	.017	.012	.010
C	.016	.043	.015	.022	.012	.008	.006	.006
DESK NO. 6.—SOUTHEAST EXPOSURE								
0	0.031	0.073	0.046	0.030	0.024	0.017	0.016	0.014
2	.029	.070	.040	.032	.020	.016	.014	.012
5	.014	.027	.018	.017	.011	.010	.009	.005
8	.007	.011	.008	.007	.008	.005	.005	.006
10	.005	.006	.005	.004	.005	.004	.004	.004
A	.029	.069	.043	.029	.021	.016	.014	.012
B	.017	.020	.030	.024	.013	.015	.010	.009
C	.012	.025	.012	.020	.010	.008	.006	.006

TABLE E.—*Hourly mean values of the sky brightness ratio (means of 9 monthly values) for each of 24 selected school desks, arranged for each hour and class of clouds, Hagerstown, Md., September 17, 1923, to June 15, 1924*—Continued

ROOM NO. 104

Clouds	Inside-illumination sky brightness ratio							
	All hours	9.40	10.40	11.40	12.40	1.40	2.40	3.40
DESK NO. 7.—NORTHWEST EXPOSURE								
0	0.024	0.019	0.019	0.018	0.022	0.022	0.029	0.041
2	.023	.019	.018	.018	.019	.021	.031	.038
5	.014	.016	.008	.011	.011	.016	.016	.017
8	.008	.008	.006	.007	.008	.007	.010	.012
10	.005	.005	.005	.005	.005	.006	.006	.006
A	.022	.018	.018	.017	.019	.020	.028	.033
B	.017	.008	.015	.017	.014	.021	.019	.024
C	.009	.009	.007	.007	.011	.010	.009	.011
DESK NO. 8.—NORTHWEST EXPOSURE								
0	0.024	0.020	0.020	0.019	0.023	0.022	0.028	0.037
2	.024	.020	.020	.019	.019	.022	.031	.035
5	.014	.018	.009	.012	.012	.016	.016	.016
8	.009	.008	.006	.008	.008	.007	.011	.012
10	.006	.006	.005	.005	.006	.006	.006	.006
A	.021	.019	.019	.018	.020	.020	.026	.028
B	.017	.008	.016	.017	.015	.020	.019	.023
C	.009	.010	.007	.007	.011	.010	.009	.010
DESK NO. 9.—NORTHWEST EXPOSURE								
0	0.018	0.016	0.016	0.016	0.018	0.017	0.020	0.024
2	.017	.015	.016	.016	.014	.016	.021	.020
5	.010	.013	.006	.009	.009	.011	.010	.010
8	.006	.006	.005	.005	.006	.006	.007	.007
10	.004	.004	.004	.004	.004	.004	.004	.004
A	.016	.014	.015	.015	.016	.015	.018	.019
B	.012	.006	.012	.013	.010	.015	.013	.014
C	.007	.007	.006	.005	.008	.007	.007	.007
DESK NO. 10.—NORTHWEST EXPOSURE								
0	0.073	0.056	0.054	0.056	0.064	0.074	0.093	0.112
2	.071	.056	.058	.057	.059	.071	.101	.096
5	.056	.055	.035	.054	.048	.078	.061	.060
8	.046	.044	.035	.039	.046	.047	.050	.059
10	.039	.035	.035	.035	.036	.038	.057	.039
A	.067	.058	.054	.053	.059	.065	.089	.090
B	.063	.037	.060	.056	.057	.071	.072	.085
C	.045	.039	.038	.040	.048	.049	.051	.050
DESK NO. 11.—NORTHWEST EXPOSURE								
0	0.152	0.085	0.084	0.088	0.111	0.146	0.217	0.335
2	.165	.090	.097	.093	.112	.157	.283	.320
5	.111	.085	.056	.088	.081	.156	.138	.174
8	.082	.067	.058	.068	.075	.081	.102	.122
10	.059	.055	.056	.057	.060	.058	.064	.066
A	.135	.088	.086	.084	.016	.136	.199	.244
B	.124	.060	.090	.099	.099	.143	.149	.229
C	.083	.065	.060	.061	.087	.099	.101	.111
DESK NO. 12.—NORTHWEST EXPOSURE								
0	0.165	0.087	0.085	0.090	0.112	0.141	0.235	0.408
2	.178	.090	.095	.100	.149	.164	.285	.366
5	.120	.089	.057	.088	.074	.143	.159	.228
8	.083	.067	.059	.066	.078	.081	.103	.127
10	.059	.054	.055	.057	.058	.059	.064	.065
A	.147	.088	.086	.097	.110	.144	.215	.291
B	.134	.060	.090	.105	.102	.151	.159	.268
C	.093	.063	.120	.062	.088	.094	.103	.121

TABLE E.—*Hourly mean values of the sky brightness ratio (means of 9 monthly values) for each of 24 selected school desks, arranged for each hour and class of clouds, Hagerstown, Md., September 17, 1923, to June 15, 1924*—Continued

ROOM NO. 204

Clouds	Inside-illumination sky brightness ratio							
	All hours	9.40	10.40	11.40	12.40	1.40	2.40	3.40
DESK NO. 13.—NORTHWEST EXPOSURE								
0	0.020	0.016	0.016	0.014	0.018	0.016	0.025	0.034
2	.019	.016	.015	.015	.014	.015	.024	.036
5	.011	.013	.006	.009	.009	.012	.013	.013
8	.006	.005	.005	.005	.006	.005	.006	.008
10	.004	.003	.003	.003	.004	.004	.004	.004
A	.018	.014	.019	.015	.015	.016	.022	.027
B	.013	.007	.011	.012	.012	.014	.014	.020
C	.007	.008	.005	.005	.009	.007	.007	.009
DESK NO. 14.—NORTHWEST EXPOSURE								
0	0.019	0.017	0.018	0.015	0.018	0.016	0.020	0.027
2	.018	.017	.017	.016	.014	.015	.022	.027
5	.010	.013	.006	.010	.009	.011	.012	.010
8	.006	.006	.005	.005	.006	.005	.006	.008
10	.004	.004	.004	.004	.004	.004	.004	.004
A	.017	.016	.017	.016	.015	.015	.019	.023
B	.013	.007	.012	.012	.012	.014	.014	.017
C	.007	.008	.006	.006	.008	.007	.007	.008
DESK NO. 15.—NORTHWEST EXPOSURE								
0	0.012	0.012	0.013	0.011	0.012	0.011	0.012	0.015
2	.011	.012	.012	.011	.009	.010	.012	.014
5	.006	.009	.006	.006	.006	.007	.006	.005
8	.004	.004	.004	.003	.004	.003	.003	.004
10	.003	.004	.003	.002	.003	.003	.002	.002
A	.011	.012	.013	.012	.011	.009	.011	.012
B	.008	.004	.008	.009	.007	.009	.010	.008
C	.005	.008	.004	.003	.005	.004	.004	.005
DESK NO. 16.—NORTHWEST EXPOSURE								
0	0.051	0.043	0.043	0.042	0.046	0.048	0.063	0.070
2	.052	.043	.042	.045	.043	.049	.064	.076
5	.038	.045	.024	.037	.034	.047	.043	.039
8	.030	.031	.024	.026	.031	.027	.033	.037
10	.026	.024	.024	.025	.025	.027	.028	.026
A	.046	.041	.040	.043	.042	.042	.057	.059
B	.042	.028	.040	.038	.038	.048	.046	.054
C	.031	.027	.026	.026	.032	.036	.033	.035
DESK NO. 17.—NORTHWEST EXPOSURE								
0	0.143	0.083	0.082	0.085	0.104	0.132	0.194	0.323
2	.145	.087	.082	.093	.109	.136	.215	.300
5	.104	.084	.052	.077	.080	.126	.145	.164
8	.073	.063	.054	.061	.067	.068	.090	.107
10	.055	.051	.051	.054	.056	.055	.060	.061
A	.127	.083	.083	.092	.101	.123	.161	.244
B	.113	.054	.081	.087	.090	.130	.130	.217
C	.076	.068	.058	.054	.081	.085	.089	.096
DESK NO. 18.—NORTHWEST EXPOSURE								
0	0.132	0.066	0.067	0.069	0.089	0.115	0.182	0.336
2	.136	.070	.068	.075	.094	.125	.220	.298
5	.090	.067	.040	.064	.066	.108	.132	.156
8	.060	.050	.044	.050	.056	.056	.075	.090
10	.044	.040	.041	.043	.045	.043	.048	.050
A	.116	.067	.068	.075	.085	.105	.169	.243
B	.101	.043	.065	.074	.075	.118	.111	.223
C	.065	.057	.047	.044	.070	.072	.076	.090

TABLE E.—*Hourly mean values of the sky brightness ratio (means of 9 monthly values) for each of 24 selected school desks, arranged for each hour and class of clouds, Hagerstown, Md., September 17, 1923, to June 15, 1924*—Continued

ROOM NO. 207

Clouds	Inside-illumination sky brightness ratio							
	All hours	9.40	10.40	11.40	12.40	1.40	2.40	3.40
DESK NO. 19.—SOUTHEAST EXPOSURE								
0	0.027	0.058	0.040	0.025	0.021	0.015	0.016	0.014
2	.027	.072	.037	.025	.017	.014	.015	.012
5	.012	.023	.014	.016	.008	.011	.009	.006
8	.007	.014	.008	.007	.007	.005	.005	.006
10	.005	.006	.005	.004	.005	.005	.004	.004
A	.026	.058	.039	.028	.019	.014	.014	.012
B	.016	.022	.024	.020	.012	.013	.012	.007
C	.010	.019	.011	.008	.010	.007	.006	.006
DESK NO. 20.—SOUTHEAST EXPOSURE								
0	0.038	0.090	0.058	0.034	0.028	0.019	0.019	0.016
2	.037	.101	.050	.035	.024	.017	.018	.014
5	.016	.027	.019	.022	.014	.014	.011	.007
8	.010	.021	.011	.009	.009	.005	.006	.006
10	.005	.008	.006	.005	.005	.005	.005	.004
A	.037	.090	.057	.037	.025	.019	.017	.013
B	.021	.029	.034	.026	.017	.016	.010	.012
C	.013	.032	.015	.011	.012	.009	.007	.007
DESK NO. 21.—SOUTHEAST EXPOSURE								
0	0.035	0.087	0.056	0.033	0.025	0.016	0.016	0.012
2	.034	.095	.046	.034	.022	.016	.015	.011
5	.014	.021	.019	.019	.014	.012	.009	.006
8	.008	.019	.010	.008	.008	.004	.005	.005
10	.004	.006	.004	.004	.004	.004	.003	.004
A	.035	.085	.056	.037	.023	.016	.015	.010
B	.019	.025	.034	.026	.015	.014	.010	.009
C	.013	.035	.015	.009	.011	.007	.005	.006
DESK NO. 22.—SOUTHEAST EXPOSURE								
0	0.214	0.477	0.384	0.259	0.161	0.089	0.074	0.054
2	.232	.474	.471	.284	.156	.094	.092	.054
5	.118	.214	.164	.185	.074	.087	.065	.037
8	.077	.151	.105	.084	.077	.041	.040	.040
10	.039	.058	.042	.040	.038	.034	.031	.031
A	.219	.471	.395	.303	.147	.094	.074	.049
B	.147	.189	.295	.242	.109	.094	.054	.049
C	.099	.245	.135	.090	.087	.058	.040	.035
DESK NO. 23.—SOUTHEAST EXPOSURE								
0	0.265	0.587	0.439	0.309	0.199	0.123	0.108	0.092
2	.275	.586	.485	.346	.197	.106	.115	.089
5	.176	.387	.210	.234	.128	.121	.095	.059
8	.110	.201	.139	.117	.108	.071	.067	.068
10	.066	.087	.073	.069	.066	.059	.056	.055
A	.275	.575	.482	.350	.200	.128	.109	.083
B	.201	.312	.370	.284	.146	.128	.085	.079
C	.127	.246	.196	.128	.114	.085	.060	.060
DESK NO. 24.—SOUTHEAST EXPOSURE								
0	0.199	0.549	0.283	0.180	0.132	0.089	0.084	0.074
2	.203	.527	.327	.188	.125	.096	.087	.070
5	.146	.429	.150	.148	.093	.082	.071	.047
8	.086	.162	.095	.079	.076	.086	.053	.054
10	.060	.073	.057	.057	.052	.090	.047	.044
A	.192	.494	.296	.197	.122	.090	.079	.066
B	.145	.306	.234	.151	.099	.092	.067	.067
C	.091	.201	.123	.075	.076	.065	.050	.048

TABLE F.—*Monthly mean values of the sky brightness ratio (means of values for only 4 or 5 certain hours*[1]*) for each of 24 selected school desks, arranged for each month and class of clouds, Hagerstown, Md., September 17, 1923, to June 15, 1924*

ROOM NO. 107

Clouds	Inside-illumination sky brightness ratio									
	All months	Oct.[2]	Nov.[2]	Dec.[2]	Jan.[2]	Feb.[2]	Mar.[2]	Apr.[2]	May[2]	June[2]
DESK NO. 1.—SOUTHEAST EXPOSURE										
0	0.144	0.147	0.160	0.175	0.190	0.174	0.150	0.143	0.092	0.066
2	.155	.149	.280	.174	.204	.182	.150	.107	.087	.065
5	.128	.158	.120	.138	.245	.136	.124	.102	.084	.048
8	.088	.088	.063	.107	.125	.112	.102	.077	.061	.054
10	.069	.066	.072	.067	.079	.082	.083	.064	.058	.050
A	.149	.142	.156	.175	.200	.199	.182	.150	.078	.056
B	.132	.136	---	.170	.177	.234	.122	.082	.071	.062
C	.093	---	.132	.125	.119	.120	.083	.062	.056	.046
DESK NO. 2.—SOUTHEAST EXPOSURE										
0	0.154	0.154	0.171	0.192	0.215	0.201	0.158	0.135	0.094	0.066
2	.167	.159	.294	.177	.243	.208	.160	.112	.083	.065
5	.138	.162	.145	.138	.269	.152	.140	.103	.082	.048
8	.089	.082	.067	.117	.132	.112	.102	.075	.060	.055
10	.068	.066	.067	.065	.078	.084	.080	.063	.056	.050
A	.160	.151	.175	.196	.222	.224	.202	.141	.076	.056
B	.137	.134	---	.179	.163	.270	.128	.081	.072	.064
C	.095	---	.138	.135	.103	.124	.038	.064	.055	.046
DESK NO. 3.—SOUTHEAST EXPOSURE										
0	0.126	0.122	0.136	0.162	0.184	0.174	0.129	0.105	0.068	0.051
2	.136	.128	.246	.148	.199	.181	.126	.085	.064	.050
5	.110	.130	.118	.132	.202	.122	.113	.076	.063	.037
8	.071	.064	.047	.100	.123	.084	.079	.059	.042	.043
10	.051	.048	.046	.048	.056	.062	.058	.059	.039	.044
A	.134	.120	.131	.169	.191	.195	.167	.128	.062	.042
B	.112	.117	---	.144	.131	.242	.099	.062	.056	.049
C	.073	---	.104	.118	.082	.102	.066	.044	.038	.031
DESK NO. 4.—SOUTHEAST EXPOSURE										
0	0.015	0.014	0.018	0.020	0.019	0.018	0.014	0.014	0.012	0.007
2	.014	.013	.012	.017	.021	.018	.016	.010	.010	.006
5	.008	.009	.007	.010	.013	.009	.011	.006	.006	.003
8	.005	.004	.005	.007	.009	.006	.007	.005	.004	.002
10	.004	.002	.004	.004	.004	.004	.006	.004	.002	.002
A	.014	.013	.016	.020	.019	.014	.018	.013	.009	.004
B	.011	.011	---	.015	.015	.018	.013	.006	.005	.005
C	.007	---	.010	.010	.012	.008	.007	.004	.003	.002
DESK NO. 5.—SOUTHEAST EXPOSURE										
0	0.018	0.017	0.022	0.024	0.023	0.021	0.017	0.017	0.016	0.009
2	.019	.021	.023	.019	.026	.021	.020	.014	.013	.006
5	.011	.011	.010	.012	.016	.012	.015	.009	.009	.004
8	.007	.005	.006	.009	.010	.008	.008	.006	.005	.003
10	.004	.003	.004	.004	.005	.005	.007	.006	.003	.002
A	.017	.016	.020	.025	.024	.017	.022	.015	.011	.005
B	.013	.012	---	.018	.019	.020	.016	.008	.007	.007
C	.008	---	.012	.012	.014	.010	.009	.005	.004	.002
DESK NO. 6.—SOUTHEAST EXPOSURE										
0	0.017	0.016	0.020	0.022	0.021	0.019	0.016	0.016	0.015	0.008
2	.016	.014	.024	.018	.021	.019	.019	.012	.012	.006
5	.010	.009	.009	.010	.015	.010	.013	.008	.008	.004
8	.006	.004	.005	.008	.009	.007	.008	.005	.004	.002
10	.004	.002	.004	.004	.005	.005	.007	.005	.003	.002
A	.016	.016	.018	.023	.022	.014	.020	.014	.010	.004
B	.012	.014	---	.016	.017	.017	.016	.008	.006	.006
C	.008	---	.011	.010	.014	.009	.008	.005	.003	.002

[1] Hours 9.40 a. m. to 1.40 p. m. for rooms 104 and 204, and hours 12.40 p. m. to 3.40 p. m. for rooms 107 and 207.

[2] Interval ending on the 15th day of the indicated month.

TABLE F.—*Monthly mean values of the sky brightness ratio (means of values for only 4 or 5 certain hours [1]) for each of 24 selected school desks, arranged for each month and class of clouds, Hagerstown, Md., September 17, 1923, to June 15, 1924*—Continued

ROOM NO. 104

Clouds	Inside-illumination sky brightness ratio									
	All months	Oct.[2]	Nov.[2]	Dec.[2]	Jan.[2]	Feb.[2]	Mar.[2]	Apr.[2]	May [2]	June [2]
DESK NO. 7.—NORTHWEST EXPOSURE										
0	0.019	0.021	0.024	0.025	0.023	0.020	0.023	0.017	0.014	0.008
2	.019	.021	.022	.021	.024	.023	.022	.018	.014	.008
5	.013	.015	.009	.012	.017	.014	.016	.017	.011	.006
8	.007	.006	.006	.009	.009	.009	.009	.008	.005	.004
10	.005	.004	.004	.005	.005	.006	.008	.006	.005	.003
A	.018	.015	.022	.024	.024	.017	.027	.014	.014	.007
B	.017	.014	.026	.016	.029	.022	.020	.010	.007	.006
C	.010	----------	.013	.012	----------	.019	.009	.007	.005	.003
DESK NO. 8.—NORTHWEST EXPOSURE										
0	0.020	0.022	0.025	0.028	0.025	0.021	0.024	0.017	0.014	0.008
2	.020	.021	.023	.022	.027	.021	.023	.018	.015	.009
5	.014	.015	.010	.013	.019	.015	.018	.018	.012	.006
8	.008	.006	.007	.010	.010	.009	.010	.008	.006	.004
10	.005	.004	.005	.006	.006	.006	.008	.006	.005	.003
A	.020	.015	.022	.026	.027	.018	.036	.015	.014	.007
B	.017	.013	.027	.017	.030	.023	.017	.010	.008	.005
C	.010	----------	.013	.013	----------	.017	.010	.007	.005	.003
DESK NO. 9.—NORTHWEST EXPOSURE										
0	0.016	0.016	0.021	0.022	0.021	0.018	0.019	0.014	0.011	0.005
2	.016	.015	.018	.020	.022	.016	.018	.014	.011	.006
5	.010	.010	.008	.010	.015	.012	.012	.013	.009	.004
8	.006	.004	.005	.007	.008	.007	.007	.006	.004	.003
10	.004	.002	.003	.004	.004	.005	.007	.005	.003	.002
A	.015	.011	.017	.021	.023	.014	.023	.012	.010	.005
B	.013	.009	.022	.012	.022	.017	.016	.008	.005	.003
C	.007	----------	.009	.010	----------	.011	.007	.005	.003	.002
DESK NO. 10.—NORTHWEST EXPOSURE										
0	0.060	0.063	0.073	0.079	0.076	0.064	0.069	0.048	0.044	0.025
2	.061	.067	.069	.068	.084	.069	.061	.048	.053	.028
5	.058	.078	.037	.059	.078	.062	.083	.062	.040	.027
8	.042	.036	.043	.057	.048	.052	.047	.041	.029	.024
10	.036	.027	.034	.042	.043	.041	.044	.036	.032	.024
A	.058	.051	.066	.073	.085	.068	.077	.042	.037	.023
B	.061	.060	.082	.061	.092	.071	.072	.044	.038	.026
C	.048	----------	.065	.072	----------	.071	.043	.036	.032	.018
DESK NO. 11.—NORTHWEST EXPOSURE										
0	0.102	0.115	0.125	0.128	0.123	0.104	0.116	0.081	0.074	0.049
2	.110	.134	.139	.116	.133	.130	.113	.076	.100	.053
5	.100	.149	.063	.102	.120	.097	.148	.109	.071	.042
8	.071	.063	.070	.094	.092	.079	.076	.069	.052	.041
10	.058	.048	.056	.065	.066	.066	.069	.053	.053	.042
A	.100	.101	.122	.109	.132	.118	.129	.073	.072	.048
B	.103	.103	.141	.113	.147	.128	.116	.076	.064	.042
C	.082	----------	.124	.093	----------	.141	.070	.061	.050	.033
DESK NO. 12.—NORTHWEST EXPOSURE										
0	0.101	0.095	0.128	0.129	0.126	0.107	0.119	0.080	0.081	0.047
2	.117	.136	.143	.115	.140	.167	.117	.083	.097	.053
5	.098	.153	.061	.101	.121	.098	.124	114	071	.042
8	.071	.062	.068	.097	.091	.082	.077	.071	.053	.039
10	.057	.047	.054	.064	.065	.065	.069	.053	.052	.041
A	.106	.102	.141	.121	.133	.123	.138	.078	.069	.047
B	.108	.112	.148	.114	.163	.132	.121	.074	.065	.039
C	.081	----------	.124	.098	----------	.144	.070	.061	.038	.030

[1] Hours 9.40 a. m. to 1.40 p. m. for rooms 104 and 204, and hours 12.40 p. m. to 3.40 p. m. for rooms 107 and 207.

[2] Interval ending on the 15th day of the indicated month.

TABLE F.—*Monthly mean values of the sky brightness ratio (means of values for only 4 or 5 certain hours*[1]*) for each of 24 selected school desks, arranged for each month and class of clouds, Hagerstown, Md., September 17, 1923, to June 15, 1924*—Continued

ROOM NO. 204

Clouds	Inside-illumination sky brightness ratio									
	All months	Oct.[2]	Nov.[2]	Dec.[2]	Jan.[2]	Feb.[2]	Mar.[2]	Apr.[2]	May[2]	June[2]
DESK NO. 13.—NORTHWEST EXPOSURE										
0	0.016	0.016	0.020	0.023	0.020	0.017	0.018	0.013	0.009	0.006
2	.015	.015	.020	.019	.024	.014	.016	.015	.010	.006
5	.010	.014	.006	.010	.014	.011	.011	.012	.008	.005
8	.005	.004	.004	.007	.007	.006	.006	.006	.004	.004
10	.004	.003	.004	.004	.004	.004	.005	.004	.003	.002
A	.016	.012	.019	.022	.022	.012	.026	.012	.011	.005
B	.012	.010	.022	.014	.021	.016	.013	.007	.004	.004
C	.007	----------	.010	.010	----------	.011	.006	.005	.003	.002
DESK NO. 14.—NORTHWEST EXPOSURE										
0	0.017	0.017	0.021	0.025	0.021	0.018	0.019	0.014	0.010	0.006
2	.016	.014	.020	.020	.023	.014	.017	.015	.011	.006
5	.010	.013	.006	.010	.015	.012	.011	.014	.008	.004
8	.005	.005	.004	.007	.007	.006	.006	.006	.004	.003
10	.004	.003	.003	.005	.004	.004	.006	.004	.003	.002
A	.016	.011	.019	.023	.024	.012	.023	.012	.011	.005
B	.013	.009	.020	.015	.022	.017	.014	.007	.005	.004
C	.007	----------	.009	.011	----------	.012	.007	.005	.003	.002
DESK NO. 15.—NORTHWEST EXPOSURE										
0	0.012	0.010	0.014	0.019	0.016	0.013	0.013	0.010	0.006	0.003
2	.011	.008	.014	.015	.017	.011	.013	.010	.007	.003
5	.007	.007	.005	.007	.011	.008	.008	.008	.006	.002
8	.003	.002	.002	.005	.005	.005	.004	.004	.002	.002
10	.003	.002	.002	.003	.003	.003	.005	.003	.002	.001
A	.011	.007	.013	.017	.018	.009	.018	.009	.007	.003
B	.008	.005	.014	.009	.016	.012	.009	.005	.003	.002
C	.005	----------	.006	.007	----------	.008	.005	.003	.002	.003
DESK NO. 16.—NORTHWEST EXPOSURE										
0	0.044	0.043	0.052	0.060	0.057	0.049	0.050	0.034	0.029	0.018
2	.044	.046	.052	.045	.061	.054	.047	.035	.036	.018
5	.039	.049	.025	.037	.049	.051	.052	.042	.028	.021
8	.028	.023	.026	.036	.031	.034	.031	.030	.022	.017
10	.025	.021	.023	.029	.029	.030	.029	.024	.022	.016
A	.042	.036	.053	.056	.061	.044	.057	.030	.024	.018
B	.041	.033	.053	.045	.066	.050	.052	.030	.023	.018
C	.032	----------	.042	.039	----------	.049	.032	.018	.027	.014
DESK NO. 17.—NORTHWEST EXPOSURE										
0	0.096	0.108	0.116	0.118	0.119	0.100	0.113	0.074	0.069	0.047
2	.103	.125	.130	.106	.127	.122	.104	.085	.083	.047
5	.089	.142	.061	.086	.098	.101	.105	.098	.060	.046
8	.064	.064	.060	.078	.071	.073	.064	.071	.052	.041
10	.055	.057	.052	.061	.060	.061	.061	.051	.048	.040
A	.097	.099	.124	.114	.126	.115	.121	.068	.062	.045
B	.094	.094	.120	.097	.150	.116	.106	.068	.056	.042
C	.077	----------	.109	.092	----------	.141	.067	.052	.046	.032
DESK NO. 18.—NORTHWEST EXPOSURE										
0	0.080	0.093	0.099	0.097	0.097	0.084	0.092	0.064	0.056	0.038
2	.087	.106	.113	.088	.104	.096	.089	.072	.076	.039
5	.073	.119	.052	.072	.076	.085	.086	.082	.048	.036
8	.053	.051	.051	.063	.058	.060	.052	.063	.044	.032
10	.042	.035	.040	.049	.049	.049	.047	.044	.036	.031
A	.082	.084	.102	.095	.100	.092	.102	.057	.072	.036
B	.080	.078	.100	.085	.136	.101	.088	.057	.048	.031
C	.065	----------	.094	.076	----------	.125	.055	.044	.037	.024

[1] Hours 9.40 a. m. to 1.40 p. m. for rooms 104 and 204, and hours 12.40 p. m. to 3.40 p. m. for rooms 107 and 207.

[2] Interval ending on the 15th day of the indicated month.

TABLE F.—*Monthly mean values of the sky brightness ratio (means of values for only 4 or 5 certain hours [1]) for each of 24 selected school desks, arranged for each month and class of clouds, Hagerstown, Md., September 17, 1923, to June 15, 1924*—Continued

ROOM No. 207

Clouds	Inside-illumination sky brightness ratio									
	All months	Oct.[2]	Nov.[2]	Dec.[2]	Jan.[2]	Feb.[2]	Mar.[2]	Apr.[2]	May[2]	June[2]
DESK NO. 19.—SOUTHEAST EXPOSURE										
0	0.016	0.015	0.019	0.020	0.020	0.017	0.015	0.015	0.014	0.008
2	.015	.014	.022	.016	.022	.016	.016	.012	.012	.007
5	.010	.012	.016	.009	.009	.010	.012	.008	.008	.005
8	.006	.004	.006	.009	.008	.006	.006	.004	.004	.004
10	.004	.004	.004	.004	.004	.005	.006	.005	.004	.003
A	.015	.013	.017	.022	.021	.014	.020	.013	.010	.005
B	.012	.013	----------	.016	.018	.014	.014	.008	.006	.006
C	.007	----------	.010	.010	.010	.008	.007	.005	.004	.003
DESK NO. 20.—SOUTHEAST EXPOSURE										
0	0.020	0.018	0.023	0.024	0.025	0.022	0.019	0.018	0.017	0.010
2	.019	.017	.028	.021	.026	.023	.020	.014	.014	.008
5	.012	.015	.019	.011	.011	.014	.016	.011	.009	.006
8	.007	.006	.007	.010	.010	.007	.008	.005	.004	.005
10	.005	.004	.005	.005	.005	.006	.007	.006	.004	.003
A	.018	.016	.020	.026	.024	.017	.025	.016	.012	.007
B	.015	.018	----------	.020	.021	.020	.017	.010	.007	.008
C	.009	----------	.013	.012	.015	.010	.008	.006	.005	.003
DESK NO. 21.—SOUTHEAST EXPOSURE										
0	0.017	0.016	0.019	0.021	0.022	0.020	0.016	0.014	0.013	0.008
2	.017	.016	.026	.019	.024	.021	.015	.011	.012	.007
5	.011	.013	.016	.010	.010	.013	.013	.009	.008	.005
8	.006	.005	.006	.008	.009	.006	.006	.004	.004	.004
10	.004	.004	.004	.004	.004	.004	.005	.004	.003	.002
A	.016	.016	.018	.023	.023	.016	.021	.012	.011	.005
B	.013	.016	----------	.017	.016	.018	.014	.007	.006	.007
C	.008	----------	.012	.011	.012	.007	.006	.005	.004	.003
DESK NO. 22.—SOUTHEAST EXPOSURE										
0	0.090	0.094	0.099	0.106	0.137	0.129	0.094	0.065	0.048	0.038
2	.105	.110	.181	.106	.152	.131	.092	.090	.052	.035
5	.076	.102	.133	.073	.058	.098	.087	.058	.044	.030
8	.052	.046	.057	.068	.073	.053	.045	.055	.029	.038
10	.034	.035	.036	.034	.038	.040	.035	.031	.028	.025
A	.091	.099	.096	.112	.124	.131	.121	.062	.045	.029
B	.083	.098	----------	.126	.084	.174	.065	.044	.035	.040
C	.054	----------	.089	.083	.063	.064	.047	.036	.026	.021
DESK NO. 23.—SOUTHEAST EXPOSURE										
0	0.125	0.133	0.144	0.146	0.174	0.162	0.130	0.099	0.078	0.060
2	.141	.144	.236	.148	.209	.172	.133	.089	.085	.056
5	.107	.152	.173	.097	.081	.126	.116	.093	.071	.051
8	.081	.074	.096	.092	.113	.086	.072	.084	.053	.059
10	.059	.059	.063	.057	.068	.068	.062	.057	.051	.046
A	.127	.136	.138	.160	.169	.164	.167	.094	.071	.047
B	.117	.123	----------	.167	.124	.227	.106	.071	.057	.061
C	.079	----------	.121	.119	.093	.083	.075	.055	.046	.038
DESK NO. 24.—SOUTHEAST EXPOSURE										
0	0.091	0.099	0.107	0.106	0.122	0.107	0.098	0.074	0.060	0.049
2	.099	.104	.162	.106	.139	.110	.096	.068	.063	.046
5	.077	.113	.123	.068	.056	.086	.075	.072	.055	.042
8	.062	.059	.076	.069	.076	.067	.055	.059	.045	.048
10	.048	.048	.050	.048	.056	.055	.052	.046	.042	.038
A	.092	.091	.102	.112	.116	.102	.116	.096	.052	.040
B	.086	.102	----------	.117	.100	.146	.078	.052	.044	.051
C	.060	----------	.089	.082	.074	.068	.056	.041	.038	.031

[1] Hours 9.40 a. m. to 1.40 p. m. for rooms 104 and 204, and hours 12.40 p. m. to 3.40 p. m. for rooms 107 and 207.

[2] Interval ending on the 15th day of the indicated month.